Fifteenth Annual Report of the Commissioners of the State Reservation at Niagara

Oct. 1, 1897 - Sept. 30, 1898

OLD MILL RACE, WILLOW ISLAND.

FIFTEENTH ANNUAL REPORT

OF THE

COMMISSIONERS

OF THE

State Reservation at Niagara.

TRANSMITTED TO THE LEGISLATURE FEBRUARY 1, 1899.

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IN ASSEMBLY,

FEBRUARY 1, 1899.

FIFTEENTH ANNUAL REPORT

OF THE

Commissioners of the State Reservation at Niagara.

NEW YORK, *January* 27, 1899.

To the Honorable the Speaker of the Assembly:

Sir.—I transmit herewith for presentation to the Legislature the Fifteenth Annual Report of the Commissioners of the State Reservation at Niagara for the fiscal year ending September 30, 1898.

Respectfully,

ANDREW H. GREEN,

President.

FIFTEENTH ANNUAL REPORT

OF THE

COMMISSIONERS

OF THE

STATE RESERVATION AT NIAGARA

FOR THE FISCAL YEAR FROM

OCTOBER 1, 1897, to SEPTEMBER 30, 1898.

Commissioners:

ANDREW H. GREEN, President.

GEORGE RAINES, CHARLES M. DOW,

THOMAS P. KINGSFORD, ALEXANDER J. PORTER.

Treasurer and Secretary:

HENRY E. GREGORY.

Superintendent:

THOMAS V. WELCH.

REPORT.

To the Honorable the Legislature of the State of New York:

The Commissioners of the State Reservation at Niagara, as required by law, submit their report for the fiscal year begun October 1, 1897, and ended September 30, 1898, being their fifteenth annual report.

The Commissioners have work of a two-fold nature to carry on at Niagara — first, that of maintenance; second, that of restoration and improvement. Of the former, it is only necessary to say that it has proceeded with its usual regularity, a detailed account of it being contained in the report of the superintendent which is appended to this report.

The work of restoration and improvement also has been continued during the year, in accordance with the plan and purpose of the Commissioners, and with gratifying results. It has consisted largely of grading, filling, riprapping, sodding and planting. The approach to Goat Island, for example, has been graded and riprapped, the shore of Bath Island (now Green Island) has been graded, and filled with soil where that treatment was needed; the inner margin of the loop-driveway at Port Bay has been graded and sodded, while its outer shore or bank has been riprapped.

There has been considerable filling and grading along the riverway, especially below Fourth street. It may be stated that the construction of the loop-driveway at Port Bay, and the filling in that has been done at different points within the Reservation has somewhat increased the acreage of the State's property at Niagara.

There is more land requiring care and attention than there was in 1885, when the Reservation was opened to the public, and consequently more money is needed for maintenance.

The Hall building, or pavilion, so long a conspicuous object in Prospect Park, was destroyed by fire in January, probably by an incendiary. There can be no doubt that the destruction of this building has improved the appearance of the grove in which it was situated. The debris has been removed, and the cellar space filled, graded and sodded. Prospect Park is a grove of very limited area, and the presence of cheap and unornamental structures within its boundaries can only be regarded as unsuitable and obtrusive. Convenience and necessity alone justify the retention of those structures that still remain. The Inclined Railway building is not tolerable from an aesthetic point of view, but it has been found convenient for the office of the Superintendent and necessary for the railway. It can never be anything but an ill-looking structure, whether seen from the grove, from the International bridge, or from the Queen Victoria Niagara Falls Park. Located as it is, in close proximity to the American Fall, it obstructs the finest view that could otherwise be had of both the American and Horseshoe Falls from the grounds It is the one unsightly building remaining.

A small house that was occupied by the Inclined Railway operator, situated near the northern boundary of the grove, and overlooking the gorge, has also been removed, and the ground raised so as to afford a better prospect of the lower river.

An elevation of earth and rock has been substituted at Hennepin's View for the observation platform that had been there for some years.

The most considerable and noteworthy improvement in Prospect Park has been effected by removing the old parapet wall at Prospect Point. It is at this point that visitors are wont to congregate

Gorge View, Prospect Park.

in order to gaze at the American Fall, since the nearest and best view of it is here obtainable. The wall afforded ample security to those who wished to approach as nearly as possible to the edge of the cataract. But it was not in accord with the surroundings. Photographs of this portion of the Reservation taken about 1845 show it in its natural state. To restore Prospect Point to something like this natural state, was the purpose of the Commissioners in directing the removal of the parapet wall. Another consideration was the condition of the bluff upon which the wall rested. The constant soaking which it receives from the water and spray of the falls made necessary frequent observations of the soil. Portions of the bluff to the northward had occasionally, through disintegration, become loosened and fallen, and it was not unnatural to apprehend some such occurrence at the Point itself. In other words, the removal of the parapet wall could not much longer have been postponed without endangering the safety of visitors.

The soil now slopes gradually down to the margin of the river, and the former artificially is succeeded by a pleasing natural appearance. An iron railing provides a safeguard for visitors.

The Commissioners were able, during the summer, to begin work upon a stone arched bridge from Goat Island to the First Sister Island, an improvement contemplated for some years. While the wooden structure that had been there so long, was safe, it was not suitable, and could not be regarded as permanent.

In 1893 the Commissioners had ordered the preparation of plans of a stone bridge to be substituted for the wooden one when the requisite amount should be forthcoming.

At the last session of the Legislature a sufficient sum of money was appropriated for the purpose. Advertisements for bids were inserted in the local and neighboring newspapers, and in due time the contract for the construction of the bridge was awarded, the

Commissioners agreeing to furnish the stone to the contractor. Although the bridge was not completed prior to the close of the fiscal year, it may not be inappropriate to give a brief description of it.

It is built of native sandstone of rustic finish, with a clear span sixty feet in width, the pathway being twelve feet wide. The total length of the bridge, including abutments, is one hundred and twenty feet; the rise of the arch is nine feet, and the extreme heighth of the pathway above the river bed is seventeen feet.

On the Goat Island side a semi-circular bay gives variety to the lines of the abutment and additional space for visitors to linger and enjoy the view of the rapids without obstructing the pathway. There is a similar bay on both sides of the Sister Island approach. The parapet walls are of large stones, rock faced. The pathway is asphalted. The abutments are built on the solid rock, and the stone work already has a dark gray coloring which harmonizes with the surroundings. The bridge altogether seems to be exceptionally well built. Although at present rather massive in appearance, when partially overgrown with vines it will be an exceedingly picturesque and graceful object.

The State, in establishing the Reservation, did something more than put an end to the mis-treatment of the Niagara scenery; it did something more than provide a pleasuring ground for the people; it made a noteworthy contribution to the cause of popular education. By terminating private ownership of the islands and shore of the Niagara, and proceeding to restore them to a more natural condition, the State gave to individuals the opportunity of contemplating and the privilege of being influenced by a great natural phenomenon in the midst of agreeable surroundings. A stimulus was thus given to the appreciative study of Nature in one of her most wonderful manifestations.

Whether the people in sufficient numbers have taken advantage of this opportunity and made the most of this privilege is a question that may be differently answered by different persons. It must be admitted, however, that the stay of most visitors at the falls is too brief to be followed by the best results. Those who obtain the greatest benefit from a visit to Niagara are they who tarry long enough to become intimately acquainted, so to speak, with all the varieties of the scenery. It is impossible to know nature well without long-continued study. A recent writer has pointed out that the first requisite in the study of nature is contemplation, which implies deliberation, leisure, receptivity. The appreciation and enjoyment of natural scenery are not, save in exceptional instances, parts of one's natural endowment. Cultivation is absolutely essential.

The importance of natural scenery in the life of the people is not likely to be over-estimated. In this age, when the tendency of so large a proportion of the population is towards cities and the artificialities of urban existence, when the exactions of business life are so incessant, when the dominance of the practical and materialistic forces is so recognizable, the importance of natural scenery as an educating and restoring agency in the popular life is greater than ever before.

"If, as seems likely," says a contemporary writer, "we can bring into definite shape, by educative means, the emotions which lead to pleasure in the landscape, we shall thereby add another important art to those which serve to dignify our lives."

The Reservation has been the means of attracting the attention of individuals to the desirability and advantage of the acquisition by the State, or people, of places remarkable for striking natural scenery, or interesting historical associations.

There are in this State not a few such places and objects that might with general approval be taken by the State and made public

possessions for all time. Money expended in fostering a love for natural scenery and stimulating a popular interest in national or local history must be regarded as money well invested.

Niagara as a great producer of power, in the development of manufacturing and electrical industries, is not likely to be neglected; it is as an educating force that the river and falls of Niagara are in danger of being disregarded. The current of the upper river has a commercial value with difficulty computed, but recognizably great which the State through its law-makers has seen fit to dispose of to corporations without exacting compensation.

As the city of Niagara Falls is to be, if it is not already, one of the most conspicuous and important manufacturing centres in the country, with the consequent development of the commercial and materialistic element, it would seem more than ever desirable that the Reservation should receive legislative, as well as popular attention, and that its natural attractions, freed from artificialities, should stand out in more striking and vivid contrast to the factories and other useful but unornamental structures that are so distinctly and obtrusively visible both above and below the Falls.

It should not be forgotten that the Reservation really belongs to the State, to the whole State and not to any portion or section of it. The organized movement for the protection of the scenery of the Falls had its origin in the great city at the mouth of the Hudson. The same city is assessed for more than one half of the State taxes. Local interest in the Reservation is entirely subordinate to the interest of the State.

The volume of the river and cataract at Niagara is of course dependent upon the water supply of the Great Lakes. The Niagara river is but the overflow of Lake Erie, into which flows the waters of the other lakes. The lowering of the level of these lakes would diminish the flow into Lake Erie, and reduce the volume of

the Niagara river. Any very large withdrawal or diversion of water from one or more of the Great Lakes would scarcely fail to be noticeable in a reduced flow at the cataract.

The Commissioners deem it advisable that the National government be requested to appoint a commission to confer with a Canadian commission as to the means to be devised to prevent any excessive diversion of the waters of the Great Lakes, and to consider the whole subject of the uses and control of these waters, and to report its conclusions to Congress, with such recommendations as it may desire to submit.

The Commissioners have been careful to avoid anything approaching extravagance, and by adopting prudent and business-like methods they have endeavored to secure an adequate return for moneys paid out. No expenditure of theirs, so far as is known, has ever been unfavorably criticised in the public prints, nor has any voucher been rejected by the State Comptroller, upon whom is imposed by law the duty of auditing the bills and approving the accounts of the Commissioners. They have, by giving in their annual reports full information of their receipts and expenditures, invited attention to their disbursement of public money and to their management of the Reservation.

They have endeavored to keep in view the interests and benefits of the people. The people paid for the Reservation, and they should have the fullest enjoyment of it.

Monthly Receipts from the Reservation.

	Inclined railway.	Rentals.	Interest on balances in bank.	Dividends.	Conscience.
1897.					
October	$284 80				$6 00
November	49 50				
December	28 60		$11 00		
1898.					
January	37 40				
February	50 70			$14 17	
March	64 00		24 97		
April	56 80				
May	218 50				
June	288 35		25 81	14 17	
July	1,096 85	$302 10			
August	1,367 50	800 00			
September	1,022 35	700 00	15 34		
	$4,565 35	$1,802 10	$77 12	$28 34	$6 00

Inclined railway	$4,565 35
Rentals	1,802 10
Interest on balances in bank	77 12
Dividends	28 34
Conscience	6 00
Total	$6,478 91

Monthly pay-rolls were as follows:

1897.	
October	$1,796 03
November	1,448 70
December	1,320 66
1898.	
January	1,396 02
February	1,333 66
March	1,495 67
April	1,780 16
May	1,795 12
June	1,798 48
July	1,799 80
July, supplemental	496 37
August	1,497 56
September	1,376 23
Total	$19,334 46

Maintenance expenditures, as per abstract, were as follows:

Abstract CV	$2,386 77
Abstract CVI	3,414 64
Abstract CVII	5,933 11
Abstract CVIII	2,272 99
Abstract CIX	2,460 34
Abstract CX	9,155 97
	$25,623 82

Improvement abstracts were as follows:

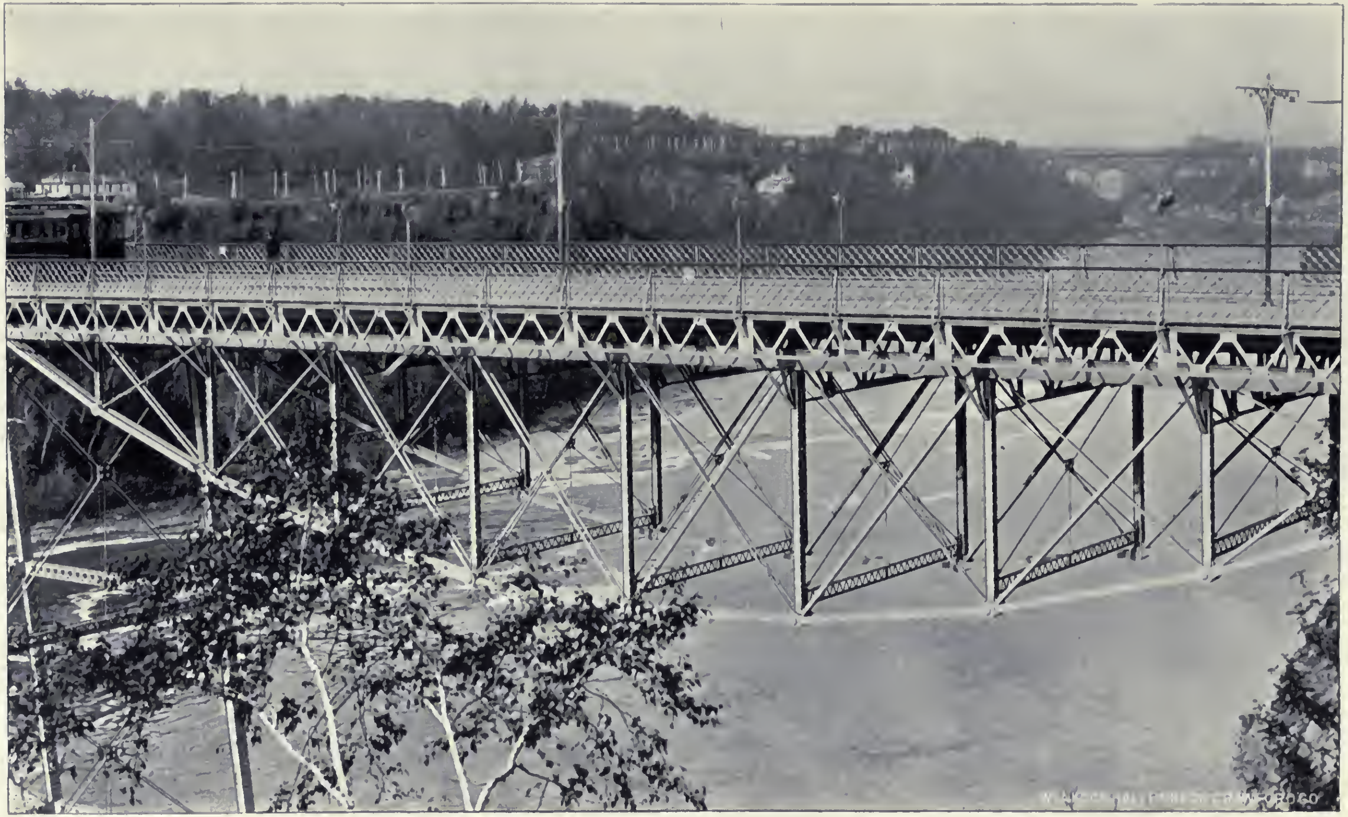
Abstract II, series H	$2,406 39
Abstract III, series H	1,296 19
Abstract IV, series H	1,944 07
Abstract V, series H	1,333 85
	$6,980 50
Abstract I, series I	5,063 03

The receipts and earnings of the Reservation have been sent to the State Treasurer monthly, and interest on balances in the Manufacturers & Traders' Bank, Buffalo, has been remitted to the same official quarterly.

The Comptroller has advanced to the Commissioners quarterly a fourth part of the $25,000 appropriated by chapter 306, Laws of 1897.

Of the treasurer's report herewith submitted, exhibiting in detail all receipts and disbursements for the fiscal year ending September 30, 1898, the following is a summary:

Balance on hand October 1, 1897		$758 53
Receipts.		
Inclined railway	$4,565 35	
Rentals	1,802 10	
Interest	77 12	
Dividends	28 34	
Conscience	6 00	
		6,478 91
From the State treasury (chapter 306, Laws of 1897)		25,000 00
From the State treasury (chapter 790, Laws of 1897)		6,980 50
From the State treasury (chapter 606, Laws of 1898)		5,063 03
		$44,280 97



Looking Northward from Gorge View.

Payments.

Pay rolls at Niagara (maintenance)......	$19,334 46	
Repairs, materials, superintendent's expenses, etc........................	4,878 93	
Treasurer's salary and expenses.........	1,163 85	
Commissioners, traveling expenses, etc..	246 58	
		$25,623 82
Remitted to State Treasurer.........................		6,478 91
Improvements (chapter 790, Laws of 1897).........		6,980 50
Improvements (chapter 696, Laws of 1898).........		5,063 03
Balance September 30, 1898......................		134 71
		$44,280 97

Total receipts since organization of the Commission, 1883..	$534,493 02
Total disbursements	534,358 31
Balance	$134 71

The Legislature has made appropriations for maintenance, current expenses and salaries, as follows :

By chapter 336, Laws of 1883....................	$10,000 00
By chapter 656, Laws of 1887....................	20,000 00
By chapter 270, Laws of 1888....................	20,000 00
By chapter 569, Laws of 1889	25,000 00
By chapter 84, Laws of 1890.....................	20,000 00
By chapter 144, Laws of 1891....................	20,000 00
By chapter 324, Laws of 1892....................	20,000 00
By chapter 414, Laws of 1893....................	25,000 00
By chapter 654, Laws of 1894....................	25,000 00

By chapter 807, Laws of 1895	$25,000 00
By chapter 948, Laws of 1896	25,000 00
By chapter 306, Laws of 1897	25,000 00
By chapter 593, Laws of 1898	25,000 00
Total	$285,000 00

For special improvements appropriations have been made as follows:

By chapter 570, Laws of 1889	$15,000 00
By chapter 302, Laws of 1891	15,000 00
By chapter 356, Laws of 1892	15,000 00
By chapter 726, Laws of 1893	25,000 00
By chapter 358, Laws of 1894	20,000 00
By chapter 932, Laws of 1895	20,000 00
By chapter 950, Laws of 1896	10,000 00
By chapter 790, Laws of 1897	15,000 00
By chapter 606, Laws of 1898	15,000 00
Total	$150,000 00

In compliance with statutory directions, the Commissioners have remitted to the State treasury the receipts from the Reservation, as follows:

From October 1, 1887, to September 30, 1888	$9,331 55
From October 1, 1888, to September 30, 1889	7,393 77
From October 1, 1889, to September 30, 1890	7,670 29
From October 1, 1890, to September 30, 1891	9,327 67
From October 1, 1891, to September 30, 1892	9,823 03
From October 1, 1892, to September 30, 1893	10,923 85
From October 1, 1893, to September 30, 1894	9,251 43

From October 1, 1894, to September 30, 1895	$6,179 09
From October 1, 1895, to September 30, 1896	7,448 01
From October 1, 1896, to September 30, 1897	7,551 83
From October 1, 1897, to September 30, 1898	6,478 91
Total	$91,379 43

The following is "an estimate of the work necessary to be done and the expenses of maintaining said Reservation for the ensuing fiscal year," ending September 30, 1899:

Construction.

Administration building and alteration of inclined railway building	$20,000 00
Grading, stairways, approaches, guard railings, and necessary improvements at Goat Island and Luna Island	5,000 00
Water pipes	2,000 00
Electric lighting	2,000 00
Planting	1,000 00
	$30,000 00

Maintenance.

Salaries, office and traveling expenses	$4,750 00
Reservation police and caretakers	5,400 00
Labor	7,500 00
Materials, tools, etc	6,000 00
Miscellaneous	1,350 00
Total	$25,000 00

Estimated receipts from October 1, 1898, to September 30, 1899:

Inclined railway	$5,500 00
Cave of the Winds	1,200 00
Ferry and steamboat landing	500 00
Carriage service	100 00
Interest	100 00
	$7,400 00

The Niagara river has a particular interest for scientific persons. Affording, as it does, an index of the lapse of geologic time, it is important that accurate measurements by trained scientists should from time to time be made, in order that the recession of the falls may be noted and other changes marked.

ANDREW H. GREEN.
GEORGE RAINES.
ALEXANDER J. PORTER.
THOMAS P. KINGSFORD.
CHAS. M. DOW.

Commissioners of the State Reservation at Niagara.

Report of the Superintendent

OF THE

STATE RESERVATION AT NIAGARA

FOR THE

Fiscal Year Ending September 30, 1898.

Report of the Superintendent.

To the Commissioners of the State Reservation at Niagara:

Gentlemen.— The most important work of the year was the construction of the stone arched bridge from Goat Island to the First Sister Island, according to plans prepared by Vaux & Emery, architects, New York city.

STONE ARCHED BRIDGE TO FIRST SISTER ISLAND.

The span of the bridge is 60 feet. Inside width 12 feet, outside width 16 feet. The bridge is constructed of native stone, of the locality.

Early in the month of July the old wooden bridge was removed and a temporary bridge constructed further up the stream. The contract for the construction of the stone arched bridge was let to W. A. Shepard, of Niagara Falls. The contract price was $5,044. The stone for the construction of the bridge was furnished by the Commissioners. The work upon the bridge was commenced July 18, 1898, and the last stone was laid in place November 4, 1898. The total cost of the bridge was $7,831.04, being less than one-half of the estimated cost.

Since the completion of the bridge the approaches have been filled and graded and the side walls banked up in readiness for planting. In the spring the grading will be completed and vines and shrubs planted about the bridge.

Photographs of the stone arched bridge are herewith submitted.

DEEPENING THE CHANNEL.

While the bridge was being built a cofferdam was placed by the contractor in the channel, above the bridge; advantage was taken of this to deepen the channel by blasting out the rock in the stream from one to two feet, so as to insure a larger volume of water upon the completion of the bridge, which spans the stream just below the Hermit's Cascade. For several years the water between Goat Island and the First Sister Island has been very low. The deepening of the channel will tend to restore the former volume of water.

PROSPECT POINT.

In the last report of the Superintendent attention was called to the artificial constructions at Prospect Point, on the brink of the American Falls, the principal point of view within the Reservation, where a stone wall enclosure, with cut-stone coping, stone stairs, a plank walk and a plank platform marred the natural beauty of the scene. During the past year all of these artificial constructions have been removed, and a great change made in the appearance of the locality.

The parapet wall has been taken down to the surface of the ground, and the wall covered with ledges of rock, laid in cement. On the arch of the Inclined Railway, where the wall bulges out, an excavation was made, and a bed of rock, laid in cement, to prevent further movement by the action of the frost. The stone steps at Prospect Point were removed. Inside the parapet wall, at Prospect Point, an excavation was made down to the solid rock and large rustic stones laid in Portland cement. The wall was then removed on the Rapids side. The outlet from the Inclined Railway was covered with flag stones. Prospect Point was widened up

Removing Stone Wall, Prospect Point, September, 1898.

stream, a shore line of large rustic stones laid, and the enlarged space at Prospect Point filled with gravel and a floor of ledges of rock laid in, so as to restore, as nearly as possible, the natural appearance of the place.

Inside the stone wall, stone posts, 12x14 inches, 4 feet long, were placed (care being taken to avoid the straight lines of the stone wall), and a substantial iron railing, of the pattern designed by Mr. Calvert Vaux, erected.

The plank walk along the stone wall was removed, and a spacious walk of ledges of rock, laid in sand, substituted. A few rustic stones were placed, the gravel walks at Prospect Point rearranged, and the low ground adjacent to the stone walk filled and covered with grass sod.

Photographs showing the changes made at Prospect Point are herewith submitted.

HENNEPIN'S VIEW.

Hennepin's View is a projecting point upon the high bank, about midway between the American Falls and the northern boundary of the Reservation, commanding the best general view of the Falls from the American side. It was occupied by a plank platform, reached by ascending a flight of wooden stairs. During the past year the wooden platform and steps have been removed and an elevation of earth and rock made upon the locality, resembling as closely as possible, a natural formation. A space has been arranged for seats for visitors upon the point of view and the walk carried over the elevation, around which a substantial guard railing has been erected.

A photograph of Hennepin's View is herewith submitted.

GORGE VIEW.

The northern boundary of the Reservation was marked by a wire fence. In the northwest corner was a frame cottage occupied by one of the employes. During the past year the cottage, fences and sheds at this point have been removed. The site of the cottage commands a fine view of the Niagara Gorge, and the international bridges to the northward. This point has been raised, the high bank riprapped with large rustic stones, and a new and desirable view opened to visitors. The walks at Gorge View have been rearranged, a space for seats for visitors provided, and an iron guard railing erected around the point of view. Gorge View has already become a favorite place of observation for visitors. The northern boundary of the Reservation is now marked by rustic stones placed at irregular intervals.

PROSPECT PARK.

The northwestern portion of Prospect Park was low and wet, and not in keeping with the other portion of the gronnds. During the past year an opportunity occurred of obtaining a large quantity of earth for filling, without expense of hauling. The low ground in Prospect Park has been drained, filled, graded and covered with grass sod, making a remarkable change in the appearance of the locality.

ROADS.

A portion of the old road in Prospect Park has been discontinued, and a loop driveway constructed, making a continuous and easy drive through the grounds. The loop drive in Prospect Park commands the prospect at Gorge View and gives access to the pavilion in the picnic grounds.

Repairs have been made upon the roads in Prospect Park and on Goat Island. Extensive repairs of the macadam roads within the Reservation will be needed during the coming year.

BUILDINGS.

January 28, 1898, the Hall building in Prospect Park was destroyed by fire of incendiary origin, as no fire had been kept in the building for two months previous to that time. A number of seats and stage fixtures were destroyed with the building. The greatest loss caused by the fire was the destruction of several fine trees adjacent to the building, showing the mistake of locating destructible frame buildings in such places.

The Hall building was long, low and unsightly; it obstructed the view, and its removal added much to the appearance of the grounds. It was, however, very convenient for public gatherings, and accessible to visitors in case of sudden rain-storms, and the need of a building for such purposes has been very great during the past summer.

During the year the library or art gallery building, one gate house, two of the refreshment booths, three closets, as well as the dwelling house and adjoining structures, all frame buildings, have been removed from Prospect Park, relieving it of a cluttered appearance, opening the view of the scenery and restoring to the place a grove-like character.

Two frame structures have been removed from the riverway, one from Green Island and one from Goat Island.

A storehouse, made necessary by the removal of the buildings in Prospect Park, has been built in the lumber yard on Goat Island. Extensive repairs were made upon the copper roof of the lower terminal station of the Inclined Railway. The open pavilion in Prospect Park and the office of the Commissioners on Green Island were renovated and an additional building provided at the cottage on Goat Island.

PLANTING.

The inner shore of the pond at Port Day, which was prepared for planting last year, has been planted with shrubs and vines, which have been carefully pruned and cultivated during the year. In addition to the stock in the nursery, 250 dogwoods, 250 honeysuckles, 100 yellow willows, 100 creeping roses, 100 Virginia creepers and 100 Japanese ivy have been procured for planting.

As soon as the weather will permit in the spring some planting should be done along the Riverway, on Green Island, adjacent to the stone arched bridge from Goat Island to the First Sister Island, and at the approach to Goat Island. Some tree planting should also be done in Prospect Park to replace the natural growths, some of which are showing signs of decay.

THE RIVERWAY.

During the past winter the outer shore of the Loop Driveway, at Port Day, was damaged by erosion, caused by high water and floating ice. During the year the entire outer shore of the driveway has been riprapped with large stones, obtained near by, at only the cost of hauling.

Since riprapping the shore has withstood the action of the ice and water, and it now presents a more permanent and natural appearance.

The neighborhood of the Loop Driveway has become one of the most attractive portions of the Reservation.

REMOVAL OF RETAINING WALL.

On the Riverway, below Fourth street, the slope adjacent to the roadway was sustained by a high retaining wall, artificial and unsightly in appearance. During the year the wall has been

removed and the stones carted to Goat Island for use in the construction of the new stone arched bridge.

The slope on the Riverway has been riprapped with large rustic stones to sustain the bank, upon which is a number of fine trees. The bank has been graded and covered with grass sod and now presents a sloping and natural appearance.

FILLING AND GRADING ON THE RIVERWAY.

The shore on the Riverway has been filled and graded from the Boulder bridge up to Fourth street, adding considerably to the land area in that locality and restoring, approximately, the original shore line. The filling and grading are not yet completed. In the spring new walks may be constructed and some planting done in that locality.

The bluff or terrace on the Riverway commands unequalled views of the rapids, the islands, and the upper Niagara river. The walks upon the bluff should be extended and improved so as to make the locality more accessible to visitors.

THE WING.

The locality immediately above Willow Island is known as "The Wing." A massive stone wall has been constructed at that point to deflect waters from the river into "The Race," a channel which conveyed it to mills which have been removed. The water inside the wall is a foot or two higher than the water in the river. The outlet from the Wing is in a dilapidated condition and should be reconstructed in a suitable manner. Parts of the Wing wall have fallen away, and if the wall is to be retained some repairs should be made. The wall at the upper end might be drawn in by an easy curve and connected with the mainland below Fourth street by a small stone arched bridge, and a loop walk or promenade thus

obtained somewhat similar to the Loop Driveway at Port Day. It would command a fine view of the rapids at that point and the upper Niagara river, and would undoubtedly be a favorite resort for visitors.

Suitable stone for this work can now be obtained at Port Day, probably without expense except for hauling, an opportunity which may never occur again.

WALKS.

The Riverway, from the northern boundary of Prospect Park to the south line of Niagara street, is included in the Reservation. The plank walk on the west side of the Riverway in that locality should be removed, and a spacious gravel walk with broad margins of green sward substituted, similar to those to the southward on the Riverway. This work is made more necessary by recent changes made in that locality.

APPROACH TO GOAT ISLAND.

The retaining walls, of quarry stone on either hand, at the approach to Goat Island have been removed, and rustic stone work substituted. Rustic stones have also been placed in the banks, ahead and to the right and left in the slopes, formed when the road on Goat Island was constructed.

The planting of the slopes may be done as soon as the weather will permit in the Spring.

THE SPRING ON GOAT ISLAND.

The frame platform at the Spring on Goat Island has been removed, and the space floored with ledges of natural rock, laid in sand. The Board of Health of the city of Niagara Falls has called attention to the probable pollution of the water by persons dipping pails and other vessels into the spring to obtain water. To guard

against possible contamination, it may be well to close the opening in the stone canopy of the Spring, so that the water may be obtained only through a tube.

SYSTEM OF WATER PIPES.

A two-inch water main has been laid from Falls street to the Inclined Railway building, and connections made so that the toilet rooms in the building may be kept open during the winter season, which has not been possible heretofore, because the water pipes in the grounds were surface pipes.

A general plan for an adequate system of water pipes for the grounds is needed.

During the year, an additional Drinking Fountain has been placed near the bridge to the Three Sister Islands. A water pipe should also be laid to the Cave of the Winds building.

ELECTRIC LIGHTING.

The present arrangement for lighting the grounds is not adequate. If the grounds are to be lighted at all, they should be well lighted.

A comprehensive plan for adequate lighting of the grounds is needed.

LANDSLIDES.

Two landslides occurred during the year on the high bank in Prospect Park, extending back as far as the stone post supporting the iron guard railings.

The cavities have been filled and planted with willows to retain the bank.

NUMBER OF VISITORS.

The number of visitors during the year is estimated at about 600,000. The "excursionists" to the Reservation aggregated 5,563 cars, bringing an estimated number of 356,765 passengers.

No disorders occurred, and no serious breach of the ordinances of the Reservation was committed by visitors.

LICENSED CARRIAGE DRIVERS.

Seventeen complaints have been made against licensed carriage drivers. Four drivers have been excluded from the Reservation for violation of the ordinances of the Commissioners.

Two public carriage stands, one on Bridge street and one on Falls street below the Riverway, have been abolished.

THE RESERVATION CARRIAGE SERVICE.

The Reservation carriage service has been in operation during the year. Since the completion of the Loop Driveway the route of the service has been extended to Port Day and return. One or more of the carriages will remain in the service during the winter season.

THE STEAMBOAT LANDING.

The landing has been used by the Maid of the Mist Steamboat Company. Only one boat has been in operation.

The level of the water in the river has been somewhat higher than in recent years.

ELEVATOR AT THE CAVE OF THE WINDS.

As this locality is between the American and the Horseshoe Falls, the view is unparalleled, but the winding stairway leading to it is so unsuitable and fatiguing that very few persons are enabled to enjoy the beauty of the scenery below the high bank, where a walk can be easily made along the edge of the water from the American to the Horseshoe Falls.

The waiting rooms and winding stairway of the Cave of the Winds have received the usual repairs during the year. The dressing rooms are inadequate and unsuitable. Better accommodations should be provided for the traveling public.

The Biddle staircase has been examined and found safe, but it is old and dilapidated in appearance, and affords but a fatiguing

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method of obtaining the view of the Falls from below. It should be replaced by a commodious elevator, with a free stairway attached. Such an elevator, operated for a nominal fee of five cents up or down, would furnish an estimated revenue of $5,000 a year, which, with the present revenue, mainly from the Inclined Railway, would almost render the Reservation self-sustaining.

ADMINISTRATION BUILDING.

The removal of the frame buildings from Prospect Park has given rise to the urgent necessity of a substantial administration building in that locality. It should be located convenient to the main entrance to the grounds, and in addition to the administration offices should contain waiting rooms, lavatories, toilet rooms, store rooms, a parcel room, and other conveniences for the accommodation of a large number of people. Such a building being provided, the present Inclined Railway building might be removed and an underground structure substituted, which would leave the view of the falls unobstructed.

The office building, which now shows so prominently on Green Island, then might also be removed.

SHELTER BUILDINGS.

Shelter buildings are needed at the American Fall and at the Horseshoe Fall on Goat Island, where visitors congregate in large numbers. At times of sudden rain-storms the present shelters are too far apart for public convenience.

EMPLOYES.

The regular force employed, exclusive of laborers, consists of 10 men, to wit, 1 superintendent, 1 clerk, 6 police gatemen and caretakers, and 2 Inclined Railway men, one of whom is employed during the summer season only.

Statement of number of employes on maintenance and improvement pay-rolls for the year ending September 30, 1898.

	MAINTENANCE.				CHAPTER 790, LAWS 1897.				CHAPTER 606, LAWS 1898.			
	Foreman.	Assistant foreman.	Laborers.	Teamsters.	Foreman.	Assistant foreman.	Laborers.	Teamsters.	Foreman.	Assistant foreman.	Laborers.	Teamsters.
1897.												
October	......	1	24	1	1	2	12	5	......	......	......	......
November	......	2	19	1	1	......	4	4	......	......	......	......
December	1	......	15	1	......	......	3	3	......	......	......	......
1898.												
January	1	......	14	1	......	......	5	1	......	......	......	......
February	1	......	15	1	......	......	......	......	......	......	......	......
March	1	......	21	......	......	1	11	5	......	......	......	......
April	1	......	26	......	......	2	10	2	......	......	......	......
May	1	......	24	......	......	3	17	3	......	......	......	......
June	1	......	24	......	......	3	23	3	......	......	......	......
July	1	2	33	1	......	......	......	......	......	2	24	3
August	......	1	16	......	......	......	......	......	1	3	48	7
September	......	1	16	......	......	......	......	......	1	3	42	8

TABULAR STATEMENTS.

The receipts from the Inclined Railway during the fiscal year were $4,565.05; from rentals and other sources, $1,836.44. Total receipts, $6,401.49.

Vouchers paid for material and labor, $11,795.36. Pay-rolls for maintenance and improvements, $28,593.91. Total expenditures by Superintendent, $40,389.27.

Detailed statements of the receipts and expenditures of the Superintendent, the amount of the pay-rolls for each month and the classification of the pay-rolls and accounts are hereto appended.

Respectfully submitted.

THOMAS V. WELCH,

Superintendent.

EXCURSIONS 1897–98.

1897.		Cars.	Persons.
Oct.	3. Hampden Hose Company, Reading, Pa	1	60
	Cleveland via C. and B	27	1,620
	4. Students Holy Angels Academy, Buffalo, N. Y	2	120
	5. Seneca and Cattaraugus Indians Temperance Convention	1	60
	6. Ancient and Honorable Artillery Company, Boston	6	360
	7. National Association Photo-Engravers	1	60
	9. Oswego Normal School	3	180
	Representatives N. Y. Life Insurance Company, Chicago, Ill	1	60
	10. Buffalo, N. Y	10	600
	Almond and Johnsburg, Pa	9	540
	Carbondale and Port Jervis	9	540
	13. Philadelphia, Pa	1	60
	Brotherhood of St. Andrew	5	300
	Washington and Baltimore	4	240
	15. Brotherhood of St. Andrew	3	180
	Hendrickson party, Brooklyn, N. Y.	1	60
	Delegates Brotherhood Locomotive Engineers	3	180
	18. Delegates Brotherhood Locomotive Engineers	4	240

1897.		Cars.	Persons.
Oct.	18. Brotherhood of St. Andrew	4	240
	New York, via Wabash	2	120
	19. Delegates Railway Convention (Electric)	10	600
	20. Delegates Railway Convention (Electric)	10	600
	31. Cook County Democracy, Chicago, Ill	6	360
1898.			
Feb.	7. President S. B. Dole, of Hawaii, and party	1	60
Apr.	10. Hotel Men's Benefit Association, Erie, Pa	7	420
May	7. Postponed Arbor Day excursion, Lockport, N. Y	11	660
	19. Exempt Firemen, Wilmington, Del.	1	60
	21. Central High School of Buffalo	4	240
	22. Main line Erie R. R.............	6	360
	Buffalo, via N. Y. C. and trolley ...	6	360
	24. Queen's birthday excursion........	25	1,800
	29. New York city via West Shore	10	600
	Erie Bicycle Club, Erie, Pa........	5	300
	Main line Erie R. R.............	10	600
	Buffalo, via N. Y. C. and trolley ...	20	1,200
	30. Memorial Day excursion, all sources.	40	2,400
	31. Delegates to Convention African M. E. Church	1	60
June	2. American Society Mechanical Engineers	4	240
	Buffalo street railway employes	1	60

1898.		Cars.	Persons.
June	5. From all sources	30	1,800
	8. County officials and friends, York and Ontario counties, Canada	2	120
	11. West Shore half-holiday excursion..	6	360
	Buffalo Kindergarten training class.	1	60
	American Axle Manufacturers' Association........................	2	120
	Erie R. R.......................	4	240
	12. Canadian militia from Niagara on the Lake.......................	4	240
	Sunday excursions................	35	2,100
	14. County superintendents of the poor.	2	120
	East York Farmers' Institute and Bonar Camp Sons of England....	4	240
	15. Delegates to American Water Works Association	5	300
	16. Wholesale and Retail Grocers, Dayton, Ohio	4	240
	Iroquois Indian children	......	20
	St. Thomas, Ont	5	300
	18. Syracuse and Rochester	6	360
	Employees Northey Co., Toronto...	6	360
	I. O. O. F., Monroe, Ont..........	4	249
	Reunion of Long family...........	1	60
	Saturday half-holiday excursions....	4	240
	Toronto, Ont., by boat.............	......	1,300
	19. German Social Society, Rochester, N. Y........................	1	60
	Lehigh Valley line	6	360
	Sunday excursion, all sources......	20	1,200

1898.		Cars.	Persons.
June 20.	Employees Kilgore Paperware Mfg. Co., Toronto, Ont.	4	240
21.	Shelbourne Street Methodist Church, Toronto	3	180
	Special party Minneapolis Daily Journal, Minneapolis	1	60
24.	Akron and Avon, via Erie R. R.	8	480
	Warren, Pa., via Dunkirk.	7	420
25.	Brotherhood Railway Trainmen, Toronto	4	240
	Graduating class, School No. 13, Buffalo	1	60
	Thursday Club, Lockport, N. Y.	1	60
	Foresters' Union Picnic, Lindsay, Ont	6	360
	Saturday half-holiday excursions, all sources	10	600
26.	Sunday excursion, all sources	40	2,400
27.	Graduating class, School No. 38, Buffalo	1	60
	Employees McLaughlin Carriage Works, Oshawa, Ont.	3	180
29.	City employees, Toronto, Ont.	3	180
	Junior Department Y. M. C. A., Cleveland, Ohio	13	780
30.	Presbyterian Church, Erie, Pa.	4	240
July 1.	Dominion Day excursions, all sources	50	3,000
2.	Saturday half-holiday excursion, all sources	20	1,200
	Royal Canadian Yacht Club	1	60

1898.		Cars.	Persons.
July	3. Sunday excursions, all sources.....	85	5,100
	4. from all sources..................	250	15,000
	5. New excursion, via W. N. Y. & P.	6	360
	6. Century Club, New Orleans, La....	2	120
	St. Louis Church Sunday School, Buffalo	2	120
	St. Francis Xavier Church, Black Rock........................	2	120
	7. Cumberland Valley State Normal School, Shippensburg, Pa.......	1	60
	Holy Trinity Church, Buffalo, N. Y.	5	300
	8. Kentucky Press Association.......	3	180
	Union churches, Caledonia, N. Y...	4	240
	Raymond and Whitcomb party....	4	240
	Railway surgeons, Toronto, Ont....	2	120
	Governor Wolcott and staff, Massachusetts........................	2	120
	N. Y. State Teachers, Rochester, N. Y.........................	4	240
	9. American Library Association Jamestown, N. Y..............	6	360
	Employees Coulter Clothing Mfg. Co., Hamilton, Ont............	8	480
	Saturday half-holiday excursions, all sources......................	10	600
	10. Sunday excursions, all sources.....	30	1,800
	11. Employees biscuit-makers, Toronto, Ont	4	240
	12. First Presbyterian Church, Lockport, N. Y..................	5	300

Prospect Point, September 1, 1898.

1898.		Cars.	Persons.
July 12.	Orange lodges, Toronto, Ont......	5	300
13.	Annual excursion, Baltimore and Washington....................	20	1,200
	Baptist Young People...........	6	360
14.	International Bill Posters' Convention	3	180
	Baptist Young People's Union.....	6	360
	Episcopal Church, Lockport, N. Y.	6	360
	Methodist Church, Erie, Pa.	7	420
15.	Baptist Young People's Union.....	25	1,500
16.	Baptist Young People's Union.....	60	3,600
	Newton Chautauqua party........	7	420
	Employees Cornell and Co. Blank Book and Stationery, Toronto, Ont.	3	180
	Employees G. T. R., Toronto, Ont.	10	600
	Half-holiday excursions, all sources.	20	1,200
17.	Sunday excursions, all sources......	50	3,000
18.	Baptist Young People's Union.....	6	360
	St. Vincent de Paul Society, Toronto, Ont	5	300
20.	Employees wholesale and retail grocers, Hamilton, Ont....... ..	10	600
	Baptist Young People's Union, Florida delegates...............	2	120
	Agents American Railway Association	6	360
	St. Margaret's Church, Toronto, by boat	......	400
	Buffalo, by boat..................	......	600
21.	Washington and Baltimore, via Lehigh Valley................	12	720

1898.		Cars.	Persons.
July 21.	Railway Y. M. C. A., via R, W. and O., Oswego N. Y.	12	720
	Western New York and Pennsylvania	7	420
	Columbus, Ohio, via C. and B.	10	600
	N. Y. State Bankers' Association	10	600
22.	Employees Empire Clothing Co., Toronto, Ont	5	300
	Cleveland, via C. and B. line	8	480
23.	Saturday excursions, all sources	335	20,100
	Buffalo, by boat	......	3,300
24.	Sunday excursions, all sources	84	5,040
25.	Olean, via W. N. Y. and P	7	420
26.	Dundas and Niagara on the Lake, Ont	6	360
	Buffalo, by boat	......	60
27.	Hamilton and St. Catherines, Ont, via M. C	8	480
	London, Ont	4	240
	Delaware, L. and W	8	480
	Cleveland, O., via C. and B.	5	300
	Buffalo, by boat	......	450
28.	Presbyterian Sunday School, Kenmore, N. Y.	2	120
	Order of Foresters, Toronto, Ont	5	300
	Canastota, via N. Y. C	7	420
30.	Chautauqua party, via W. N. Y. and P	7	420
	I. O. O. F., Erie, Pa., Nickel Plate,	8	480

1898.		Cars.	Persons.
July 30.	Port Jervis and Binghamton, via Erie R. R.	18	1,080
	Employes C. Brown Biscuit Mfg. Co., Toronto, Ont	18	1,080
	C. P. R	12	720
	General half-holiday excursions, all sources	20	1,200
	Buffalo, by boat	......	350
31.	Cleveland, O., via C. and B	7	420
	Buffalo	60	3,600
	Buffalo, by boat	......	300
Aug. 1.	Foresters, Guelph, Ont	8	480
	Civic holiday, Guelph, Ont., by boat	......	700
	Delegates to Labor Convention	7	420
	Detroit, Lansing and Saginaw, via G. T. R	10	600
2.	Special trolley party, Buffalo	3	180
	Toledo, via C. and B. line	7	420
	Rochester, via Erie R. R	6	360
3.	Public school, Buffalo	5	300
	Rochester, via Lehigh Valley R. R	8	480
	Mechanics and iron workers, Toronto, Ont	8	480
	Lindsay, Ont., via Grand Trunk R. R.	5	300
	St. Catherines, Ont., Sunday school	4	240
	Buffalo, by boat	......	80
4.	Akron, Ohio	17	1,020
	Hop Growers' Association, Auburn, N. Y	25	1,500
	Toledo, Ohio	10	600

1898.			Cars.	Persons.
Aug.	4.	Michigan city and western points...	30	1,800
		Apple Shippers' Association......	2	120
		Erie R. R., main line.............	20	1,200
		W. N. Y. and P..................	10	600
		Buffalo, Rochester and Pittsburg...	10	600
		Buffalo, by boat.....	......	100
	5.	Michigan, Indiana and Ohio, via Wabash R. R..................	34	2,000
		Erie and western roads...........	40	2,400
		Nickel Plate line.................	82	4,920
		Michigan Central R. R..	65	3,900
		Buffalo, by trolley...............	25	1,500
		Buffalo, by boat..................	......	150
	6.	Farmers' picnic, via R. W. and O ..	22	1,320
		Chautauqua party, via W. N. Y. and P........	9	540
		Half-holiday excursion...........	20	1,200
	7.	Cleveland, Ohio, via C. and B. R. R.	10	600
		N. Y. C. and H. R. R. R..........	20	1,200
		N. Y., L. E. and W	12	720
		Jamestown, N. Y	10	600
		Buffalo, Rochester and Pittsburg...	10	600
		Buffalo, via steam and trolley......	50	3,000
		Port Jervis	12	720
		Carbondale, Pa	11	660
		Buffalo, by boat	......	250
	8.	Civic holiday, Hamilton, Ont......	16	960
		Civic holiday, Simcoe, Ont	10	600
		Civic holiday, Toronto, Ont	12	720
		League Cycle Club, Philadelphia, Pa.	2	120

1898.		Cars.	Persons.
Aug. 8.	Lehigh Valley R. R.	12	720
	Woodstock, Ont., via G. T. R	12	720
	Buffalo, by boat	......	50
9.	Youngstown, via L. S. and M. S	10	600
	Erie, main line	10	600
	Chautauqua party, via W. N. Y. and P	8	480
	Buffalo, Rochester and Syracuse, via N. Y. C	12	720
	Milton, via G. T. R	9	540
	Buffalo, by boat	......	200
Aug. 10.	Officers and general agents New York Life Ins. Co	2	120
	Scandinavian Picnic, Cleveland, Ohio	8	480
	Special trolley party, Buffalo, N. Y	5	300
	Newmarket, Ont., by boat	......	1,500
	Buffalo, N. Y., by boat	......	50
11.	Railway Y. M. C. A., Rochester, N. Y	14	840
	National Hay Association	5	300
	Dunkirk and Erie, via L. S. and M. S.	8	480
	I. O. O. F., Hamilion, Ont	6	360
	Meadville, Pa	3	180
	Buffalo, N. Y	3	180
12.	Indiana, Michigan and Illinois	32	1,920
	Buffalo, Rochester and Pittsburg	8	480
	Baltimore, Washington and Philadelphia	12	720
	Lake Shore and Michigan Southern	10	600
	Buffalo by trolley	3	180

1898.		Cars.	Persons.
Aug. 13.	R., W. and O. picnic	10	600
	Masonic picnic, Norwich, Ont.	10	600
	Dundas Tool Works, Dundas, Ont.	10	600
	Chautauqua party, W. N. Y. and P.	8	480
	Saturday half-holiday	20	1,200
	Buffalo, by boat	......	100
14.	N. Y. C., West Shore and M. C.	30	1,800
	L. A. W., Rochester, N. Y.	10	600
	C. and B. line and trolley, Buffalo	50	3,000
15.	Agricultural Implement Mfg. Co., Brantford, Ont	4	240
	Union excursion, colored people, Toronto	6	360
	Raymond and Whitcomb excursion	2	120
	Order of Foresters, Brantford, Ont.	8	480
	Buffalo by boat	......	500
16.	Ohio, Indiana, Michigan and Illinois points	70	4,200
	Jamestown, N. Y	9	540
	Hornellsville, N. Y	9	540
	St. Thomas, Ont	7	420
	Burlington, Ont	7	420
17.	Big Four excursion, Illinois, Michigan, Indiana and Ohio	80	4,800
	Buffalo, by boat	......	200
18.	Hamilton, Dayton and Cincinnati	70	4,200
	Orangetown, Ont	7	420
	Buffalo, by boat	......	100
19.	Employees Massey-Harris Co., Toronto and Brantford, Ont	133	7,980

1898.		Cars.	Persons.
Aug. 19.	Chautauqua party................	11	660
	Rochester, Albion and Middleport, N. Y..........................	9	540
	Saturday half-holiday excursion....	25	1,500
	Employees Toronto Safe Works....	6	360
20.	Lehigh Valley..................	12	720
	Baltimore, Md..................	6	360
	Other sources	25	1,500
	Buffalo, by boat.................	......	150
21.	Pittsburg, Pa	14	840
	Rochester, Syracuse, etc...........	15	900
	West Shore....................	10	600
21.	Michigan Central	6	360
	Lehigh Valley	8	480
	Other sources....................	50	3,000
	Buffalo, by trolley................	100	6,000
	Buffalo, by boat..................	......	300
22.	Reunion Eighth Heavy Artillery...	8	480
	Buffalo, by boat..................	......	250
23.	Yunger Maennerchor Club, Philadelphia........................	2	120
	English Lutheran Church, Lockport, N. Y........................	8	480
	Lake Shore and M. S	12	720
24.	Western points, via Nickel Plate...	20	1,200
	Union excursion, lodges from Canada	20	1,200
	Corning and Elmira, via Erie R. R..	10	600
	Masonic excursion, Dansville, N. Y..	10	600
	D., L. and W...	12	720

1898.		Cars.	Persons.
Aug. 25.	Alliance, Youngstown and Cincinnati, Ohio	22	1,320
	Union churches and schools, Auburn, Syracuse, etc., N. Y.	14	840
	Order of Foresters, Cleveland, Ohio	10	600
	County officials York county, Ont.	8	480
	Buffalo, by trolley	10	600
	Buffalo, by boat	......	75
	Toronto, by boat	......	400
26.	Special Erie excursion, via C. and B. Line	18	1,080
	Lehigh Valley	12	720
27.	Knights of Pythias returning from Indianapolis	10	600
	General half-holiday excursion	25	1,500
28.	Baltimore, Washington, Wheeling, etc	22	1,320
	Cleveland, Ohio, via C. and B.	20	1,200
	Buffalo, by trolley	15	900
	Buffalo, by boat	......	120
29.	All sources	15	900
	Buffalo, by boat	......	100
30.	Lehigh Valley	13	780
	Lafayette Ave. Sunday School, Buffalo, N. Y.	3	180
	Buffalo, Rochester and Pittsburg	10	600
	Buffalo, by boat	......	150
	Toronto, by boat	......	420
31.	Rochester, N. Y., via West Shore R. R.	12	720

Stone Arched Bridge to First Sister Island, Erected 1898.

1898.		Cars.	Persons.
Aug. 31.	Cleveland and Akron, Ohio	14	840
Sept. 1.	Annual reunion Society Army of the Potomac	12	720
	Annual reunion Niagara County Veteran Ass'n....	6	360
	Newton Chautauqua party	8	480
	Hornellsville, N. Y., via Erie R. R.	12	720
	Dunkirk, N. Y., via Erie R. R.....	10	600
	Carbondale, Pa., via Erie R. R.....	12	720
	Buffalo, by boat..................	......	450
	Toronto, by boat..........	......	150
2.	Lehigh Valley	12	720
	Washington, Baltimore and Philadelphia......................	14	840
	Corning, Elmira, etc., via Erie R. R.	12	720
	Western New York and Pennsylvania R. R....................	12	720
3.	Cleveland, Ohio...........	20	1,200
	Toronto, Ont....................	30	1,800
	General half holiday excursions....	25	1,500
	Buffalo, N. Y., by boat...........	......	100
	Toronto, Ont....................	......	500
4.	New York city, via West Shore R. R........................	14	840
	Main line Erie R. R............	12	720
	Main line Lehigh Valley.........	12	720
	Main line D., L. & W............	11	660
	Cleveland, Ohio	20	1,200
	Rochester and Avon, via Erie R. R.	11	660

1898.			Cars.	Persons.
Sept.	4.	Buffalo	60	3,600
		Buffalo, by boat	......	200
	5.	Labor Day excursions, all sources	167	10,020
	6.	Jamestown, N. Y	12	720
		Bradford, Pa	13	780
		Knights of Pythias convention, Buffalo, N. Y	5	300
		Hendrickson party, Brooklyn, N. Y.	3	180
		Raymond and Whitcomb party	3	180
		Toronto fair	30	1,800
		Toronto, by boat	......	700
	7.	Dunkirk and Allegany	12	720
		Toronto, via G. T. R	50	3,000
		Toronto, via boat	......	500
	8.	Cleveland, Akron, Cincinnati	15	900
		Salem, Ohio	12	720
		Toronto fair, via G. T. R	50	3,000
		Toronto fair, via boats	......	4,000
	9.	Public Press Ass'n, Brooklyn, N. Y.	2	120
		G. A. R. delegates from Cincinnati	2	120
		Toronto, Ont., via G. T. R	67	4,020
		Toronto, Ont., via boats	......	2,900
		Buffalo, N. Y	42	2,520
		Lewiston, N. Y	45	2,700
	10.	New York Central R. R	30	1,800
		Buffalo, N. Y	30	1,800
		Buffalo, via boat	......	300
		Toronto, via boat	......	500
		Toronto, via Gorge Road	40	2,400

1898.		Cars.	Persons.
Sept. 11.	N. Y. C., L. V. and W S., R, W. & O. and Erie R. Rs.	203	12,180
	Cleveland, Ohio	17	1,020
12.	Foresters' convention	10	600
	Return of Co. E, 3d N. Y. V. I., excursion	20	1,200
15.	Traveling Locomotive Engineers...	2	120
	Locomotive Firemen's Ass'n......	4	240
16.	Wabash line	12	720
	Locomotives Firemen's Ass'n, Toronto	3	180
	Lakewood, N. J	3	180
17.	Olean, Salamanca, and Bradford....	9	540
18.	Main line N. Y. C., W. S. and R., W. & O	60	3,600
	Main line Erie and D., L. & W....	22	1,320
	Cleveland, Ohio, via C. & B......	10	600
20.	City officials Milwaukee, Wis......	1	60
24.	St. Luke's church and Sunday school, Brockport, N. Y	2	120
25.	Sunday excursions, via N. Y. C., Lehigh Valley and Erie...	150	9,000
27.	Newark, N. J., Grocery Men's Association	5	300
28.	Newark, N. J., Grocery Men's Association	6	360
30.	Baltimore and Washington	14	840
	Total	5,563	356,765

Recapitulation.

	Cars.	Persons.
1897.		
October excursions	123	7,380
1898.		
February excursions	1	60
April excursions	7	420
May excursions	139	8,340
June excursions	266	17,280
July excursions	1,448	92,240
August excursions	2,071	130,265
September excursions	1,508	100,780
	5,563	356,765

Report of the Treasurer

FOR THE

Year beginning Oct. 1, 1897, and ending Sept. 30, 1898.

Report of the Treasurer.

1897.				
Oct.	1.	Balance on hand this date		$758 53
		RECEIPTS (MAINTENANCE).		
Nov.	4.	Quarterly advance from the State Comptroller	$6,250 00	
1898.				
Jan.	26.	Quarterly advance from the State Comptroller	6,250 00	
Apr.	20.	Quarterly advance from the State Comptroller	6,250 00	
July	18.	Quarterly advance from the State Comptroller	6,250 00	
				25,000 00

Special appropriation as per Chap. 790, *Laws of* 1897.

1897.			
Oct.	8.	Payment by State Comptroller on account	$921 46
	12.	Payment by State Comptroller on account	226 29
Nov.	8.	Payment by State Comptroller on account	904 30
Dec.	10.	Payment by State Comptroller on account	354 34
1898.			
Jan.	12.	Payment by State Comptroller on account	130 75

1898.			
Feb. 14.	Payment by State Comptroller on account	$89 50	
Apr. 12.	Payment by State Comptroller on account	410 18	
May 11.	Payment by State Comptroller on account	582 51	
12.	Payment by State Comptroller on account	83 25	
17.	Payment by State Comptroller on account	500 00	
June 7.	Payment by State Comptroller on account	1,444 07	
July 8.	Payment by State Comptroller on account	1,333 85	
			$6,980 50

Special appropriation as per Chap. 606, *Laws of* 1898.

July 8.	Payment by State Comptroller on account	$22 00	
1897.			
Aug. 8.	Payment by State Comptroller on account	984 56	
23.	Payment by State Comptroller on account	400 35	
Sept. 7.	Payment by State Comptroller on account	1,450 00	
15.	Payment by State Comptroller on account	2,206 12	
			5,063 03
Nov. 1.	Draft on Bank of Niagara for October receipts	$290 80	

THE WING, RIVERWAY.

Dec. 1.	Draft on Bank of Niagara for November receipts	$49 50	
31.	Draft on Bank of Niagara for December receipts	28 60	
1898.			
Feb. 1.	Draft on Bank of Niagara for January receipts	37 40	
Mar. 1.	Draft on Bank of Niagara for February receipts..........	50 70	
31.	Draft on Bank of Niagara for March receipts	64 00	
May 2.	Draft on Bank of Niagara for April receipts............	56 80	
June 1.	Draft on Bank of Niagara for May receipts	218 50	
July 2.	Draft on Bank of Niagara for June receipts..............	288 35	
Aug. 1.	Draft on Bank of Niagara for July receipts..............	1,398 95	
Sept. 1.	Draft on Bank of Niagara for August receipts............	2,167 50	
30.	Draft on Bank of Niagara for September receipts.........	1,722 35	
			$6,373 45
Feb. 18.	Dividend on deposits in Cataract Bank......................	$14 17	
June 27.	Dividend on deposits in Cataract Bank......................	14 17	
			28 34
1897.			
Dec. 31.	Interest on balances in Manufacturers and Traders' Bank....	$11 00	

1898.			
Mar. 31.	Interest on balances in Manufacturers and Traders' Bank....	$24 97	
June 30.	Interest on balances in Manufacturers and Traders' Bank....	25 81	
Sept. 30.	Interest on balances in Manufacturers and Traders' Bank....	15 34	
			$77 12
	Total		$44,280 97

EXPENDITURES.

Date.	No. of abstract.	No. of voucher.	Items.	Amount.
1897.				
Nov. 1..	CV	1481	Pay-roll for October	$1,796 03
		1482	Thomas V. Welch, superintendent, office expenses..................	35 59
4..		1483	J. E. Perkins, repairs	3 90
		1484	Globe Ticket Co., Inclined Railway tickets	22 50
		1485	Power City Lumber Co., lumber	24 02
		1486	Niagara Sand Co., gravel	94 57
		1487	John Sullivan, stone..................	112 00
		1488	Timothy Horan	13 00
		1489	Coleman Nee	144 00
		1490	John Gordon, tools.....................	9 80
		1491	Cataract Ice Co., ice.................	22 80
		1492	N. F. Hydraulic Power Manufacturing Co., electric lighting................	50 00
11..		1493	Henry E. Gregory, treasurer and secretary, office expenses	28 19
12..		1494	Alex. Henschel, clerk to president.....	13 62
		1495	National Press Intelligence Co	16 75
			Total	$2,386 77

Date. 1897.	No of abstract.	No. of voucher.	Items.	Amount.
Dec. 1	CVI	1496	Pay-roll for November	$1,448 70
		1497	Thomas V. Welch, superintendent, office expenses	47 85
6		1498	W. A. Shepard, mason work	30 25
		1499	N. F. Hydraulic Power and Manufacturing Co., electric lighting	50 00
		1500	Hardwicke & Co., tools, etc	8 04
		1501	McDonald & Welch, coal	30 50
		1502	Walker & Paterson, tools, etc	18 12
		1503	Walker & Paterson, tools, etc	15 73
		1504	Cornelius Burns, broken stone	9 00
		1505	H. Hugerman, plumbing	3 80
		1506	Jas. O'Brien, broken stone	89 00
		1507	C. Nee, broken stone	14 00
		1508	John Clifford, tools	6 94
Dec. 31		1509	Henry E. Gregory, treasurer and secretary, salary October, November and December	275 00
		1510	Pay-roll for December	1,320 66
		1511	Thomas V. Welch, superintendent, office expenses	47 05
			Total	$3,414 64
1898.				
Jan. 8	CVII	1512	P. C. Flynn & Son, painting	$94 48
		1513	J. W. Mead, brooms	12 75
		1514	O. V. Sage, agent and warden, letter heads, etc	6 25
		1515	J. E. Perkins, repairs	8 56
		1516	P. J. Davy, plumbing	110 26
		1517	Power City Lumber Co., repairs	12 08
		1518	Power City Lumber Co., repairs	21 14
		1519	Walker & Paterson, tools, etc	14 84
		1520	N. F. Hydraulic Power and Manufacturing Co., electric lighting	50 00

Date. 1898.	No. of abstract.	No. of voucher.	Items.	Amount.
Feb. 1..		1521	Pay-roll for January	$1,396 02
		1522	Thomas V. Welch, superintendent, office expenses, etc	44 67
9..		1523	Walker & Paterson, tools, etc	19 58
		1524	Jas. Davy, stationery	8 90
		1525	G. Chormann, tools	5 20
		1526	N. F. Hydraulic Power and Manufacturing Co., electric lighting	50 00
		1527	Braas Bros., raising ceiling	72 91
		1528	Braas Bros., shelves, etc	74 87
Feb. 15..		1529	Wm. Hamilton, Commmissioner, traveling expenses	52 23
Mch. 1..		1530	Pay-roll for February	1,333 66
		1831	Thomas V. Welch, superintendent, office expenses	49 80
8..		1532	Thos. E. McGarigle, repairing water wheel	26 06
		1533	Power City Lumber Co., repairing Incline Railway building	5 01
		1534	P. C. Flynn & Son, painting	94 59
		1535	Walker & Paterson, tools, etc.	19 41
		1536	McDonald & Welch, coal	60 00
		1537	Maloney & McCoy, ice	61 00
		1538	N. F. Hydraulic Power and Manufacturing Co., electric lighting	50 00
31..		1539	Henry E. Gregory, treasurer and secretary, salary January, February, and March	275 00
		1540	Pay-roll for March	1,495 67
		1541	Thomas V. Welch, superintendent, office expenses.	49 88
		1542	Alex. Henschel, clerk to president, services	50 00
		1543	Hardwicke & Co., repairs	7 89
		1544	Braas Bros., carpentering	7 01

Date. 1898.	No. of abstract.	No. of voucher.	Items.	Amount.
		1545	Braas Bros., carpentering	$148 34
		1546	Jas. Davy, stationery	3 25
		1547	Peter Lammerts, tools	40 20
		1548	Walker & Paterson, tools, etc	33 60
		1549	N. F. Hydraulic Power and Manufacturing Co., electric lighting	50 00
		1550	Fred Batchelor, seed	18 00
				$5,933 11
April 9	CVIII	1551	Omar V. Sage, agent and warden, stationery	$13 76
May 2		1552	Pay-roll for April	1,780 16
		1553	Thomas V. Welch, superintendent, office expenses	48 49
9		1554	W. A. Shepard, repairs to conduit	44 31
		1555	Thos. E. McGarigle, repairs and tools	12 63
		1556	Power City Lumber Co., lumber	12 13
		1557	Hardwicke & Co., repairs	43 93
		1558	Peter Henderson & Co., scythes	12 00
		1559	P. J. Davy, repairs	64 67
		1560	Walker & Paterson, tools, etc	22 44
		1561	P. C. Flynn & Son, painting	77 36
		1562	Jas. Davy, stationery, etc	10 20
		1563	J. McDonald, coal	15 00
		1564	N. F. Hydraulic Power and Manufacturing Co., electric lighting	50 00
		1565	Wm. Hamilton, Commissioner, traveling expenses	30 25
		1566	Henry E. Gregory, treasurer and secretary, office expenses	35 66
				$2,272 99
June 1	CIX	1567	Pay-roll for May	$1,795 12
		1568	Thomas V. Welch, superintendent, office expenses, etc	49 03

Date.	No. of abstract.	No. of voucher.	Items.	Amount.
1898.				
June 2..		1569	J. Mackenna & Son, shades, etc	$5 50
		1570	Hardwicke & Co., hose, etc	18 23
		1571	J. H. Ellenbaum, plumbing	29 21
		1572	Braas Bros., carpentering	25 34
		1573	P. C. Flynn & Son, painting	62 47
		1574	F. W. Oliver & Co., tools	25 02
		1575	P. J. Davy, plumbing	48 87
		1576	Walker & Paterson, hardware, etc	58 91
		1577	Niagara Falls Gas Light Co., gas	17 64
		1578	N. F. Hydraulic Power & Mfg. Co., electric lighting	50 00
30..		1579	Henry E. Gregory, treasurer and secretary, salary April, May and June	275 00
			Total	$2,460 34
July 1..	CX	1580	Pay-roll for June	$1,798 48
		1581	Thomas V. Welch, superintendent, office expenses	49 27
5..		1582	Walker & Paterson, tools, etc	35 45
		1583	P. J. Davy, plumbing	126 77
		1584	Braas Bros., repairs	26 61
		1585	Braas Bros., repairs	208 94
		1586	P. C. Flynn & Son, painting	159 45
		1587	Hardwicke & Co., repairs	139 18
		1588	Charlotte Haeberle, tools	5 28
		1589	Power City Lumber Co., lumber	34 64
		1590	Omar V. Sage, agent and warden, stationery	6 25
		1591	N. F. Hydraulic Power and Mfg. Co., electric lighting	50 00
		1592	N. F. Gas Light Co., gas	13 32
Aug. 1..		1893	Pay-roll for July	1,799 80
		1594	Thomas V. Welch, superintendent, office expenses	37 52
3..		1895	Supplemental pay-roll	496 37

Date. 1898.	No. of abstract.	No. of voucher.	Items.	Amount.
Aug. 3..		1596	Jas. McCarthy, tools	$25 00
		1597	Charlotte Haeberle, repairs	11 18
		1598	J. H. Cook & Co., repairs	10 28
		1599	N. F. Gas Light Co., gas	10 08
		1600	N. F. Hydraulic Power and Manufacturing Co., electric lighting	50 00
		1601	Niagara Wagon Works, tools	6 45
		1602	Carl Steinbrenner, repairs	2 16
		1603	Belmont Iron Works, park seats	181 50
		1604	Nat. Tent and Awning Co., canopy	50 00
		1605	Walker & Paterson, tools, etc.	44 06
		1606	Braas Bros., bridge repairs	19 45
		1607	Braas Bros., bridge repairs	21 58
Sept. 1..		1608	Pay-roll for August	1,497 56
		1609	Thomas V. Welch, superintendent, office expenses	19 11
10..		1610	W. F. Wall, cable for Inclined Railway	212 64
		1611	Globe ticket Co., tickets	45 00
		1612	P. C. Flynn & Son, painting	76 20
		1813	P. J. Davy, plumbing	19 71
		1614	Walker & Paterson, tools, etc	19 27
		1615	N. F. Gas Light Co, gas	4 14
		1616	N. F. Hydraulic Power and Manufacturing Co., electric lighting	50 00
		1617	W. A. Shepard, raceway repairs	37 93
		1618	Charlotte Haeberle, tools, etc	6 09
30..		1619	Pay-roll for September	1,376 23
		1620	Thomas V. Welch, superintendent, office expenses	14 29
		1621	Thomas P. Kingsford, Commissioner, traveling expenses	83 73
		1622	Henry E. Gregory, treasurer and secretary, salary July, August and September	275 00
			Total	$9,155 97

Payments out of $15,000 *as per chapter* 790, *Laws of* 1897.

Date.	No. of abstract.	No. of voucher.	Items.	Amount.
1897.	Series H.			
Oct. 14	II	13	Pay-roll, walks and grading	$851 71
		14	Samuel Parsons, Jr., traveling expenses.	25 50
		15	Fred Batchelor, seed	9 00
		16	Fred Batchelor, seed	9 00
		17	W. A. Shepard, gutters	26 25
		18	Niagara Sand Co., gravel	226 29
Nov. 10		19	Pay-roll, roads and grading	904 30
Dec. 10		20	Pay-roll, roads	354 34
			Total	$2,406 39
1898.				
Jan. 12	III	21	Pay-roll, walks	$130 75
Feb. 15		22	Pay-roll, walks and grading	89 50
April 12		23	Pay-roll, grading	410 18
		24	Pay-roll, grading	582 51
		25	W. McCulloch, survey, etc	58 50
		26	Samuel Parsons, Jr.	24 75
			Total	$1,296 19
May 17	IV	27	Walker & Morris, plans on bridge	$500 00
June 7		28	Sam'l Parsons, Jr., plans for planting, etc	400 00
		29	Pay-roll, rods and planting	787 57
		30	Elizabeth Nursery Co., shrubs	19 00
		31	Ellwanzer & Barry, vines	29 50
		32	Andorra Nurseries, shrubs	208 00
			Total	$1,944 07
July 11	V	33	Pay-roll, roads, grading, etc	$1,187 60
		34	Parsons & Sons Co., shrubs	35 75
		35	Sam'l C. Moon, shrubs	40 00
		36	George Cook, planting	43 50
		37	Sam'l Parsons, Jr., landscape architect	27 00
			Total	$1,333 85

Payments out of $15,000, *as per chapter* 606, *Laws of* 1898.

Date.	No. of abstract.	No. of voucher.	Items.	Amount.
1898.	Series I.			
July 11..	I........	1....	Cataract Publishing Co., advertising..	$2 50
		2....	Wm. Pool, advertising..................	1 75
		3....	Buffalo News, advertising..............	5 60
		4....	Gazette Publishing Co., advertising...	2 50
		5....	Buffalo Commercial, advertising	4 20
		6....	E. T. Williams, advertising...........	1 25
		7....	The Times, advertising................	4 20
Aug. 9..		8....	Buffalo Courier, advertising	3 50
		9....	Buffalo Express, advertising	3 50
		10....	Pay-roll, bridge and grading..........	977 56
24..		11....	Pay-roll, grading.....................	400 35
Sept. 8..		12....	W. A. Shepard, stone arched bridge...	1,450 00
16..		13....	Pay-roll..............................	1,464 04
		14....	B. Messing, stone arched bridge	140 00
		15....	David Phillips, stone arched bridge ...	101 67
		16....	John D. Dietrich, tools	42 40
		17....	Conway & Munson, stone arched bridge	458 01
			Total	$5,063 03

Remittances to the State Treasurer.

1897.		
Nov. 1..	Draft for October receipts..................	$290 80
Dec. 1..	Draft for November receipts	49 50
31..	Draft for December receipts	28 60
1898.		
Feb. 1..	Draft for January receipts..................	37 40
Mar. 1..	Draft for February receipts	50 70
31..	Draft for March receipts	64 00
May 2..	Draft for April receipts	56 80
June 1..	Draft for May receipts	218 50
July 2..	Draft for June receipts	288 35
Aug. 1..	Draft for July receipts	1,398 95

Sept.	1..Draft for August receipts	$2,167 50
	30..Draft for September receipts	1,722 35
	Total	$6,373 45
Mar.	1..Dividend on deposits in Cataract Bank	$14 17
June	30..Dividend on deposits in Cataract Bank	14 17
	Total	$28 34
1897.		
Dec.	31..Interest on balances in Manufacturers and Traders' Bank.	$11 00
1898.		
Mar.	31..Interest on balances in Manufacturers and Traders' Bank.	24 97
June	30..Interest on balances in Manufacturers and Traders' Bank.	25 81
Sept.	30..Interest on balances in Manufacturers and Traders' Bank.	15 34
	Total	$77 12
	Cash balance in bank	$134 71
	Grand total	$44,280 97

HENRY E. GREGORY,
Treasurer.

We, the undersigned, hereby certify that we have examined the foregoing report of the treasurer for the fiscal year ended September 30, 1898, the vouchers and other papers; and we find the report and accompanying documents correct, and that the treasurer has properly accounted for all moneys received and disbursed by him during the fiscal year ended September 30, 1898.

THOMAS P. KINGSFORD,
CHAS. M. DOW,
Commissioners of the State Reservation at Niagara.

Classification of Accounts.

Maintenance.

Commissioners' expenses	$166 21
Treasurer and secretary, office expenses	63 85
Naigara office (superintendent)	575 83
Salaries (superintendent and clerk)	2,674 98
Police	5,400 00
Inclined Railway	1,571 27
Prospect Park	3,196 53
Goat Island	2,315 34
Roads	2,423 62
Walks	1,178 75
Coal	105 50
Electric lighting	550 00
Ice	83 80
Seed	18 00
Buildings	2,573 05
Tools	362 91
Bridges	142 78
Treasurer and secretary	1,100 00
Water pipes	282 92
Expense	80 37
Plumbing	3 80
Furniture	81 88
Fixtures	5 50
Gutters	7 00
Slats	181 50
Drinking fountains	54 55
Sewers	26 38
Port Day pond	397 50
	$25,623 82

Improvements under chapter 790, *Laws of* 1897.

Planting	$459 10
Roads	1,810 26
Grading	2,731 46
Walks	835 93
Bridges	558 50
Filling	208 75
Seed	18 00
Gutters	26 65
Shrubs and vines	332 25
	$6,980 50

Improvements under chapter 606, *Laws of* 1898.

First Sister Island bridge	$2,787 24
Grading	1,341 60
Deepening channel	365 05
Iron railing	77 25
Hennepin's View	449 49
Tools	42 40
	$5,063 03

DEPARTMENT OF THE INTERIOR—U. S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

RECENT EARTH MOVEMENT

IN THE

GREAT LAKES REGION

BY

GROVE KARL GILBERT

EXTRACT FROM THE EIGHTEENTH ANNUAL REPORT OF THE SURVEY, 1896-97
PART II—PAPERS CHIEFLY OF A THEORETIC NATURE

CONTENTS.

ILLUSTRATIONS.

RECENT EARTH MOVEMENT IN THE GREAT LAKES REGION.

By G. K. Gilbert.

INTRODUCTION.

The geologic history of the earth shows that in all parts of its surface there have been great oscillations of level. Modern history also records upward and downward movement of the land at various points. The modern movements are of small amount, but it is believed that they are of the same kind as the ancient, and that the great changes of the geologic past were effected slowly. Nearly all discoveries of modern change have been made at the seashore, but there is no reason to suppose that the land is now more stable in the interior of the continents than along their coastal borders. Observations are restricted to the coast because the sea level affords the best available datum plane for comparison. The present paper discusses the stability of the region of the Laurentian lakes, and uses the surfaces of the lakes as datum levels or planes of reference.

OBSERVATIONS BY MR. STUNTZ.

In 1869 there was presented to the American Association for the Advancement of Science a paper by G. R. Stuntz, a land surveyor of Wisconsin, describing certain observations on Lake Superior made by him in 1852 and 1853. He states that in those years a certain mill race at the falls of St. Marys River was entirely dry. As St. Marys River is the outlet of Lake Superior, its volume and the supply of water for the mill race depend on the height of

water in the lake, and he therefore inferred that at that end of the lake the water was low. He also states that a small stream at Pindle's mill, entering Lake Superior not far from the outlet, runs with swift current to the lake, and has no widening, marshes, or other indication that its valley overflows by the lake setting back into it. He then describes the strongly contrasted condition of streams entering the lake near its western end.*

As you go westward, the Ontonagon River exhibits a slight filling up. The valley near the mouth shows that at the time it was excavated the surface of the lake was lower than at present. The same is also apparent at the mouth of Bad River, still farther west. At the mouth of Boise Brulé the same thing is exhibited, only to a greater extent. From this to the west end of the lake not only does the lake set back into the valleys of the streams, but the waters are making rapid encroachments on the banks. So rapidly is the filling back, that the deposits of the streams do not keep pace with the filling up. The consequence is, that there is a large marsh and pond in the mouth of the valley of Boise Brulé and Aminecan River. But nowhere is this filling up more apparent than in the bay above the mouth of the St. Louis River. In several parts submerged stumps, several feet below the present water level, are found. The numerous inlets surrounding the main bay, when we consider the nature of the soil and the formation (a tough, red clay), in all of which the water is deep, could not have been excavated in the natural course of events with the water at its present level. The testimony of the Indians also goes to strengthen the same conclusions. At the time of running the State line above mentioned, the Indians, ever jealous of their rights, called me to a council to inquire why I ran the line through Indian land. In the explanation, I gave, using the language of the law, as a starting point, the lowest rapid in the St. Louis River. The chief immediately replied that formerly there was a rapid nearly opposite the Indian village. Start, said he, from that place, and you will be near the treaty line. After he had been further questioned, I

* On some recent geological changes in northeastern Wisconsin: Proc. Am. Ass. Adv. Sci. Vol. XVIII, 1870, pp. 206-207.

learned that it was only a few years since the river was quite rapid at the Indian village. At the time the said line was run the first rapid was about one mile by the stream above the village. From these facts I conclude that a change is taking place gradually in the level of this great valley.

From these data Stuntz infers "the gradual rise of water at this [west] end of the lake and the falling of the same at the east," and it is evident from the context that he refers this change of the water to a westward canting of the basin, the western part becoming lower as compared with the eastern.

So far as I am aware, this paper broaches for the first time the idea of differential elevation in the Great Lakes region, and it contains the only observations that have ever been cited as showing recent changes of that character. In later years the subject has been approached from the geologic side, and Dr. J. W. Spencer has expressed his opinion that a warping or tilting of the whole region is now in progress.

EARTH MOVEMENTS DURING THE CLOSING EPOCHS OF THE PLEISTOCENE PERIOD.

The Great Lakes came into existence in the latest of the geologic periods, the Pleistocene. Their number and position underwent numerous and important changes during the latter part of the period, and their area and drainage systems have been greatly modified even within the time to which human history belongs. In late Pleistocene time, the great Laurentide ice field, which just before had covered the entire lake basin, was slowly growing less through the melting away of its edges, there were a series of lakes along its southern margin. These were held in at the north by ice and on other sides by uplands, and they found outlet southward over the lowest passes of the divide between the Laurentian basin and the basins of the Mississippi, Susquehanna, and Hudson. With changes

in the position of the ice barrier, individual lakes were from time to time divided or drained and separate lakes united, so that the lacustrine geography had a complex history. After the ice had wholly disappeared from the region, the drainage did not at once assume its present system, for Lake Huron, instead of overflowing to Lake Erie, discharged its surplus water over the pass at North Bay, Canada, and thence down the Mattawa and Ottawa Rivers to the St. Lawrence.

In the decipherment of this history much use is made of the shore lines of the vanished lakes. These consist of sand and gravel terraces that were once deltas, of cliffs and strands carved from hillsides by the waves, and of spits and beach ridges thrown up by the same agency. A number of these lines have been traced for great distances, and wherever thus traced it is found that they are no longer level, but are gently inclined. When formed they were of course horizontal, for they were made by waves generated on a water surface, and the fact that they are not now level shows that the land on which they are marked has undergone changes of relative height. The general direction of inclination of the shore lines is toward the south-southwest, showing that the basin of the lakes has been canted in that direction. The amount of change has not been everywhere the same, and it is probable that the direction of the canting varies somewhat from place to place. Where several shore lines are traced on the same slope the first made are usually more steeply inclined than the last made, and hence it is inferred that the general change of relative altitude was in progress through the whole epoch of the glacial lakes. The plane of the Iroquois shore line in the basin of Lake Ontario descends toward the south-southwest at an average rate of 3½ feet a mile, the slope being steeper at the north than at the south.* The Oswego shore

*J. W. Spencer, Trans. Roy. Soc. Canada, Section IV, 1889, pp. 121–131; G. K. Gibert, Sixth Ann. Rept. Commissioners of the State Reservation at Niagara, Albany, 1890.

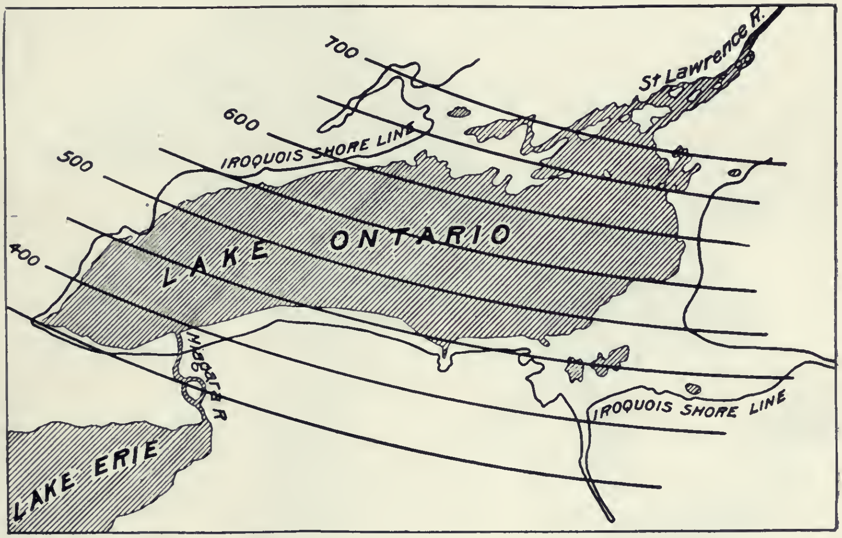


FIG. 94.—Map of the Iroquois shore line. Modern water bodies are shaded. A line shows the boundary of the ancient lake. The parallel curves are isobases.

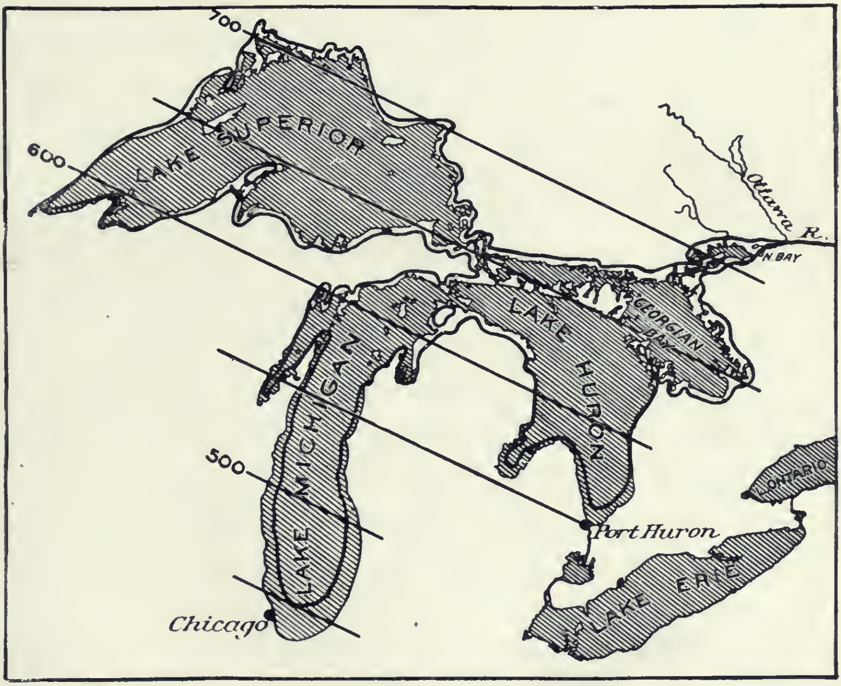


FIG. 95.—Map of the shore line of Great Lake Nipissing. Modern water bodies are shaded. A line shows the boundary of the ancient lake. The parallel lines are isobases.

line, in the same basin, slopes in the same direction at the rate of more than 3 feet a mile. The Warren shore line, traced from Lima, New York, about the sides of the Ontario, Erie and Huron basins, to Pompeii, Michigan, is nearly level in the Maumee basin, but rises northeastward with a rate gradually increasing to 2 feet a mile. Its northward rise in Michigan is 1½ feet a mile.* The present southward inclination of the water plane of Lake Algonquin, which occupies the Superior, Michigan, and Huron basins, ranges from a few inches to 3 feet a mile.† Great Lake Nipissing, which occupied the same basins after the disappearance of the ice and had its outlet at North Bay, conformed more nearly to the present slopes, the general inclination of its water plane being about 7 inches to the mile.‡

On the accompanying maps of Lake Iroquois and Great Lake Nipissing (figs. 94 and 95) the character of the tilting is shown by means of isobases, or lines drawn at right angles to the direction of tilting. All points on one of these lines have been uplifted the same amount since the time of the corresponding lake. If we think of the plane of the water surface of one of the old lakes as having been deformed by uplift or warping, then the isobases are contours, or lines of equal present height, on the deformed plane.

Other evidence of the tilting of the land is found in the character of stream channels as they approach lake shores. The streams reaching Lake Superior from the southwest have already been described in the quotation from Stuntz, and similar characters are found in the basins of Lake Erie and Lake Ontario. Considerable tracts of land along the southern shores and about the western ends of these lakes are smooth plains, there surfaces having been leveled by deposits of fine sediment from the Pleistocene lakes just men-

* F. B. Taylor, Bull Geol. Soc. America, Vol. VIII, 1897, p. 55.

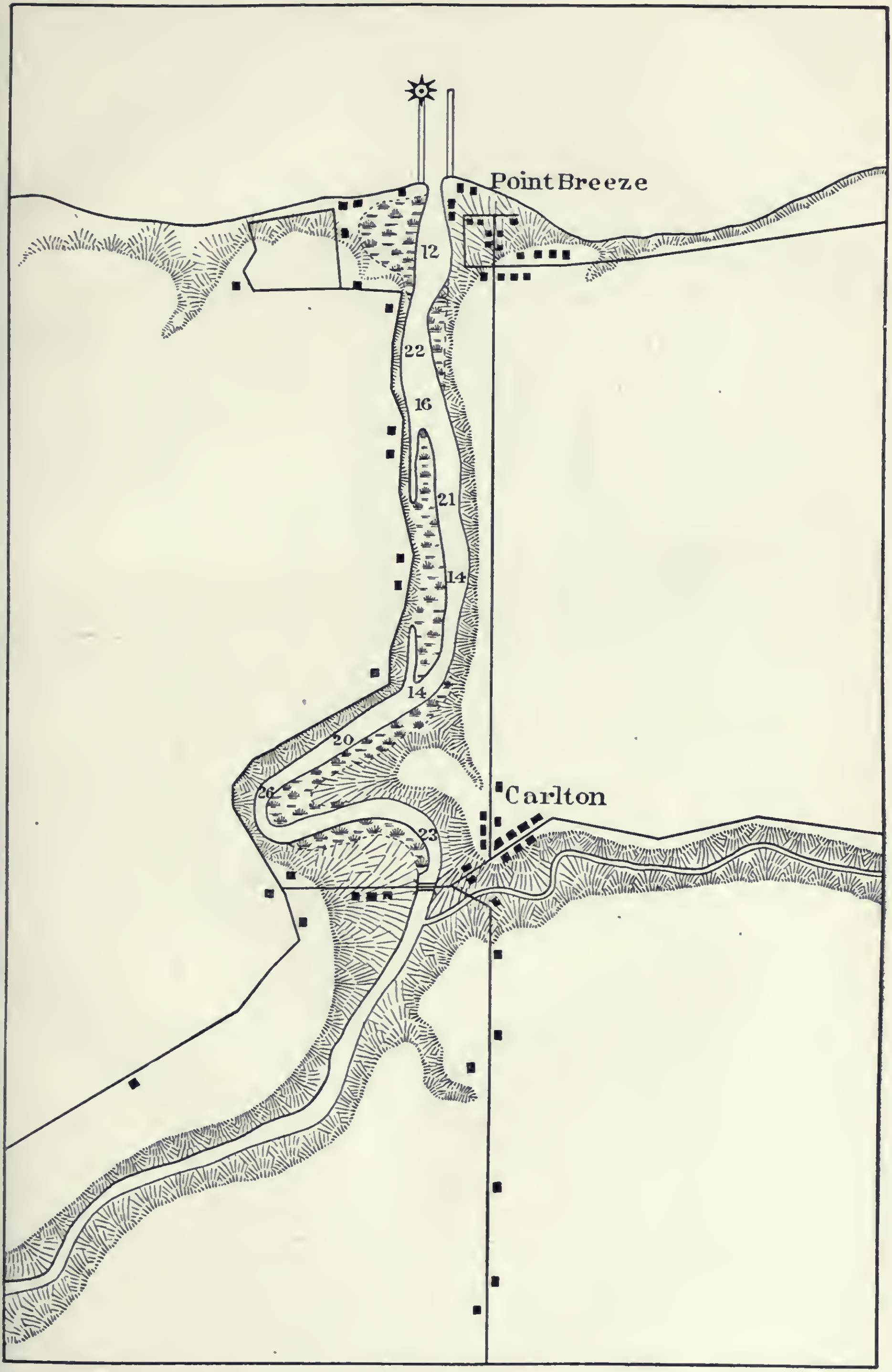
† F. B. Taylor, A Short History of the Great Lakes, Terre Haute, 1897.

‡ Ibid.

tioned. The creeks and rivers traversing the plains have readily cut the soft deposits, carving out narrow valleys. In the upper parts of these valleys the streams are shallow and descend with lively current, but on approaching the lake they become deep and sluggish, the change usually occurring several miles from the lake shore. Stated in another way, each stream, instead of debouching into the lake, enters the head of a long, narrow bay or estuary. The origin of such estuaries is well understood. They are found on all sinking coasts, and their meaning in this region is that the land has gone down or the lake level has risen, so that the waters of the lake occupy portions of the channels carved by the streams in the lowland plain. This description applies to the greater number of streams entering Lake Ontario between the Genesee and Don Rivers and to those entering Lake Erie between Cuyahoga River and Maumee Bay. Individual mention may be made of Oak Orchard, Eighteenmile and Twelvemile Creeks in New York, of Twelvemile and Twentymile Creeks and the Credit and Humber rivers in Ontario, and of Rocky River, Black River, Vermillion River, Old Womans Creek, Pike Creek, Turtle Creek and Ottawa River, in Ohio. Even the largest rivers of the district, including the Genesee, Niagara, Cuyahoga and Maumee, have features indicative of the same history.*

By reference to the map (fig. 93) it will be seen that the outlets of these lakes are at their northernmost points, and this fact is related to the conditions of the stream channels. The water level of a lake is maintained by the balance between inflow and outflow. It is just high enough to enable the outflowing stream to carry off the excess from inflow, and the height of water on all shores is thus determined by the height of the outlet. So if these basins are canted northward the outlets are thus lowered with reference to

* F. B. Taylor mentions a few other localities on the same lakes: Am. Geologist, Vol. XV, 1895, pp. 174-176.



ESTUARY AT THE MOUTH OF OAK ORCHARD CREEK, ORLEANS COUNTY, NEW YORK.
Scale, 1 inch=1,500 feet. Figures give soundings in feet.
The water ways are sharply incised in the plain. Partial refilling is shown by marshes.
Slack water at lake level reaches to Carlton, above which the creeks are shallow.

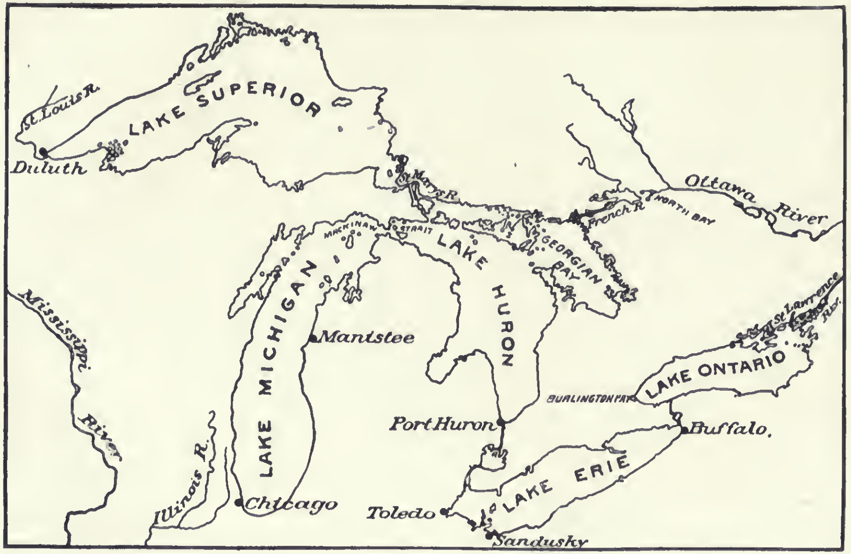


FIG. 93.—Map of Laurentian lakes.

other parts, and the waters recede on the southern shores. If they are canted southward, the outlets are raised and the waters are made to advance on the southern shores. Reasoning from effect to cause, the fact that the lake water invades the new-made stream channels on the southern shores is evidence of the southward canting.

It should not be assumed that the "drowning" of stream channels is restricted to the tracts mentioned above. Those tracts are specified because they fall within the range of the writer's personal observation and are known to exhibit the phenomena in a striking way. It is believed that similar features may be found wherever the local conditions are favorable throughout the whole coast lines of Lake Ontario and Lake Erie, about the head of Lake Michigan from Manistee, Michigan, to Kewaunee, Wisconsin, and about the whole of the American shore of Lake Superior.

REASONS FOR REGARDING A PROGRESSIVE MODERN CHANGE AS PROBABLE.

Independent of the phenomena described by Stuntz, there are various considerations tending to direct attention to the question of the stability or instability of the Laurentian area at the present time. The first to be mentioned is purely geologic. The epoch during which the overflow from the upper lakes followed the valleys of the Mattawa and Ottawa is definitely associated with a certain stage of the Niagara River. The cataract of Niagara is at the present time increasing the length of the Niagara gorge at a somewhat rapid rate. The formation from which the water leaps is a firm limestone 60 feet thick, and beneath this are shales which are comparatively soft and weak. The cataract, by eroding the shale, undermines the limestone, which falls away in blocks, and these blocks are in turn utilized by the water as an instrument with which to grind the shale. Whirled about by the water, the blocks not only wear away

the face of the shale cliff, but drill down deeply, so that beneath the cataract there is a pool nearly or quite 200 feet deep. Working in this way, the cataract has extended the gorge several hundred feet since the first accurate measurements were made, the average annual rate being between four and five feet.

With the present arrangement of the drainage system the Niagara carries the surplus water from the basins of lakes Huron, Erie, Michigan and Superior; but when the upper lakes sent their overflow to the St. Lawrence by way of the Ottawa, the Niagara carried only the discharge from the Erie basin. Its volume was only one-eighth of the present volume and its power was correspondingly less. It could not move the great blocks of limestone which fell from the cliff, and, instead of scooping out a deep pool, as now, it excavated a comparatively shallow channel, whose bottom was cumbered with limestone débris. Owing to this difference in method of erosion it is possible to discriminate the parts of the gorge excavated when the river was small and when it was large, and thus to determine the place of the cataract when the outlet of Lake Huron was shifted from North Bay and the Ottawa River to Port Huron and the St. Clair and Detroit Rivers. That place is at the head of the Whirlpool Rapids, 11,600 feet from the present cataract. Assuming that the cataract worked at its present rate through this distance, we may compute the time consumed. At four and one-half feet a year, it would be about two thousand six hundred years. F. B. Taylor, making allowance for various qualifying factors, estimates the time to have been not less than five thousand years.*

When Lake Huron changed its outlet, the plane of its water surface extended from the pass at North Bay to the pass at Port

* A short history of the Great Lakes.

Huron, but the North Bay pass now stands 140 feet higher than the Port Huron. This difference of altitude, amounting to six inches a mile, has, therefore, been wrought within the period of about five thousand years. In view of the gradual nature of such movements, this is not a long period to assign to the measured change, and it is natural to inquire whether the movement is not still in progress.

Dr. J. W. Spencer, who has devoted much time to the study of the Niagara gorge and the glacial lakes, is confident that change of level has not yet ceased, and that it will eventually turn the water of the upper lakes southward to the Illinois and Mississippi rivers, leaving the Niagara channel dry. Addressing the American Association for the Advancement of Science in 1894, he said:*

The end of the falls seems destined, if we read the future by the past, to be effected, not by the erosion expending itself on the rocks, but by terrestrial deformation turning the drainage of all the upper lakes into the Mississippi, by way of Chicago, just as the Huron waters were lately turned from the Ottawa into the Niagara drainage; and at the recent rate it would seem that about five thousand or six thousand years at most will be needed. The change of drainage should arrive before the cataract shall have receded to Buffalo.

Another consideration of the same tendency is found in the condition of the estuaries described in the last section. Most of the streams flowing into these rise in districts of unconsolidated drift and carry forward in flood time a considerable load of detritus. This is deposited in the estuaries, the coarser part making deltas at their heads, and the finer settling as mud in the deeper water. The process tends to convert the estuaries, first to marshes and then to dry land, but in most instances little

*Proc. Am. Ass. Adv. Sci., Vol. XLIII, 1894, p. 246.

progress in that direction has been made. There are a few creeks rising in sandy districts which have succeeded in filling their estuaries, changing them to marshes; but as a rule the delta at the head of the estuary invades it but a short distance, and the marshes which border it here and there at points sheltered from the flood currents are impassable except by boats, and have the appearance of submerged flood plains. These characters, from their close resemblance to the features observable along the subsiding parts of the Atlantic coast, give the impression that a slow flooding of the stream valleys is still in progress.

A third consideration is connected with the record of recent changes on the coasts of the continent. It has long been known that the Atlantic coast south of Connecticut is subsiding, and Prof. G. H. Cook was able to determine the rate in New Jersey as about two feet a century.* Dr. Robert Bell has recently collated a variety of facts tending to show that the land has risen in the region about Hudson and James bays,† and he estimates the rate at from five to seven feet a century. If these two movements are parts of a general movement affecting the northeastern part of the continent, then the Great Lakes region, approximately intermediate in position between the rising and sinking areas, should be found to exhibit a southward tilting.

These various facts, all tending in one direction, are sufficient warrant for the working hypothesis that the tilting of the lake region demonstrated by the slopes of the old shore lines is still in progress; and the writer, who has for many years been interested in the problems of the Great Lakes, has made repeated efforts to secure an investigation by which the hypothesis might be tested.

* Am. Jour. Sci., 2d series, Vol. XXIV, 1857.

†Am. Jour. Sci., 4th series, Vol. I, 1896.

The mode of investigation first suggested was the establishment of elaborate observation stations at three points—Port Huron, Chicago and Mackinac. By a suitable series of observations at these points, the relative heights of benches might be established with high precision, the water surface being used as a leveling instrument. Then, after an interval of one or two decades, the observations might be repeated and any changes in the heights of benches due to differential uplift detected. The matter was submitted in 1890 to the Superintendent of the United States Lake Survey and to the Superintendent of the United States Coast and Geodetic Survey, but, though it was received favorably by the latter officer, the work was not undertaken.

Other plans were then considered, and it was finally decided to make a study of existing records of lake level, and, if necessary, supplement them by additional observations. The results of this investigation are set forth in the following pages.

GENERAL PLAN OF INVESTIGATION.

Variations in the height of the ocean level at any place depend chiefly on tides, winds, and atmospheric pressure. By means of long series of observations the effect of these disturbing factors can be eliminated and a mean level obtained which is practically uniform from year to year and decade to decade. The height of the water surface must depend also on the quantity of water in the ocean, but the actual variations of volume are so small as compared to the extent of the ocean surface that the resulting variations of level may be neglected and the mean level used as a standard for the discussion of differential movements of the earth's crust. With the Great Lakes the case is materially different. There are variations due to wind, atmospheric pressure, and tides, but when these have been eliminated by long series of observations

the resulting mean level is far from constant, varying from season to season and year to year with the volume of water. In each lake there is an annual change of more than a foot, depending on the seasonal inequality between gain by precipitation and loss by evaporation (fig. 96), and there is a still greater change resulting from the cumulative effect of series of dry and series of moist years. The records show that the water surface in each lake has been several feet higher in some years than in others. (See fig. 97.)

For this reason the water surface of a lake does not afford a datum plane by reference to which the elevation or subsidence of coasts can be directly determined. Fortunately, however, there is an indirect method by which practically the same result may be attained. If the mean level of a lake surface be determined for two parts of the coast at the same time, these two planes may be regarded as parts of the same level surface, and, through reference to this common datum, fixed objects on the land at the two localities can be compared with each other so as to determine their relative altitudes. If, then, after an interval of time, the measurements are repeated, a change in the relative height of the fixed objects may be discovered and measured. The investigation described in the following pages made use of this method.

The fundamental principle of the method is illustrated by the diagram, fig. 98, in which A C B is the cross profile of a lake basin. At a certain time the mean plane of the water surface occupies the position XX′. By means of the engineer's level it is ascertained that a bench mark A has a certain height above the water plane at X, and that a bench mark B has a certain height above X′. The difference between these two measurements is the difference in altitude between A and B. After an interval of years the measurements are repeated. The water plane then stands at some different level, say YY′. The height of A above Y is

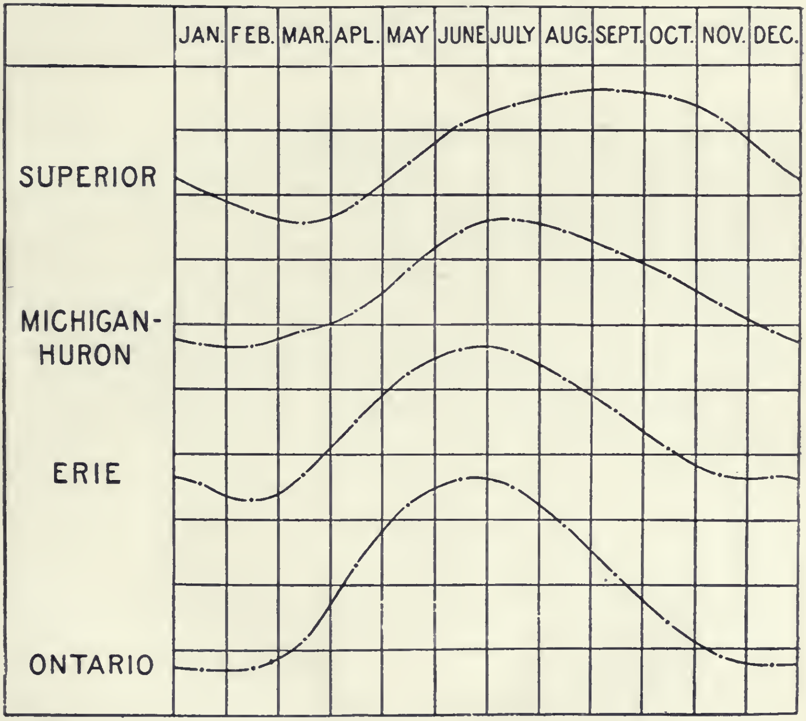


FIG. 96.—Annual oscillations of the surfaces of the Laurentian lakes. Compiled from monthly means published by the Chief of Engineers, U. S. A. Each vertical space represents six inches. The observations for Lake Superior cover the period 1862-1895; for Michigan-Huron, 1860-1895; for Erie, 1855-1895; for Ontario, 1860-1895.

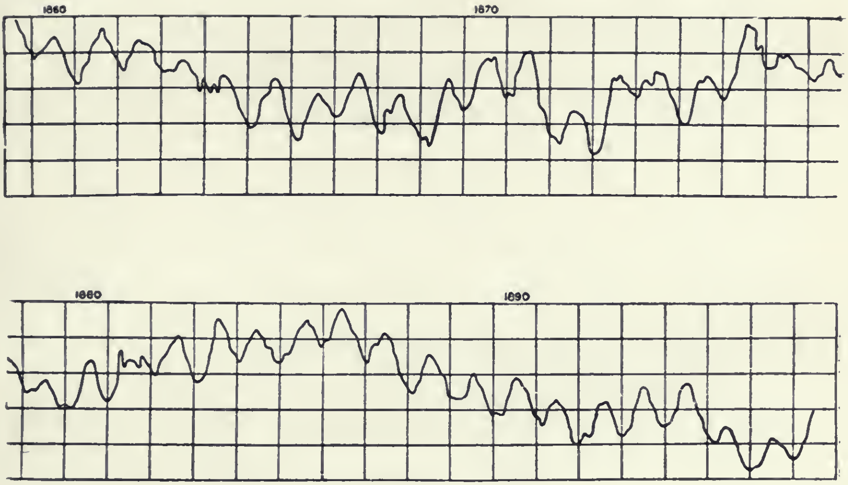


FIG. 97.—Oscillations of the surface of Lake Michigan due to changes in the volume of the lake. Compiled under the direction of the Chief of Engineers, U. S. A., from gage readings at Milwaukee, Wisconsin, from August, 1859, to June, 1897. Each horizontal space represents a calendar year; each vertical space, one foot.

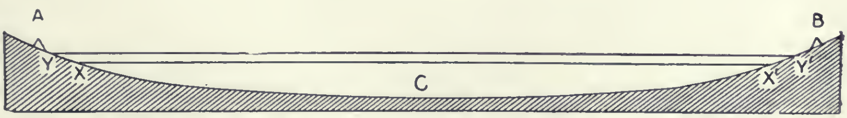


FIG. 98.—Diagram illustrating method of measuring earth movements.

measured, and the height of B above Y′; the difference between the two measurements gives the relative height of A and B. If earth movements have occurred during the interval between the two sets of measurements the second determination of the comparative height of A and B will differ from the first determination, and the amount of difference will measure the differential earth movement.

AVAILABLE DATA.

Gage readings.—In order to eliminate the temporary effects of disturbing factors, it is necessary to have a series of observations of the height of the water surface at each of the localities compared. The gages by means of which such observations are made are of various kinds. One of the simplest is a graduated plank, fixed vertically, by attaching it to a dock or other structure, so that one end is above water and the other below. Sometimes the plank is omitted and the graduation marked upon the side of a dock or pier. The height of the water surface is ascertained by direct comparison with the lines of the graduation. Another form of gage which has been extensively used in the lakes consists of a graduated rod, not fixed, but held in the hand; with this the distance from the water surface to a fixed point is measured. Usually the fixed point chosen is above the water surface, but at one station, Port Colborne, it is the submerged sill of a canal lock. Another form of gage includes a float to which a graduated vertical rod is fixed, and the graduations of the rod are compared with a fixed point on the land; or a chain attached to the float may pass over a pulley and carry a counterpoise, in which case an index, fastened to some part of the chain or counterpoise, moves up and down past a stationary graduated scale. There are also automatic gages making periodic or continuous records.

Previous to the year 1859 records of lake level are meager, and not of such nature as to be suited to the purposes of this investigation. A general account of them is given by Col. Charles Whittlesey in Volume XII of the Smithsonian Contributions to Knowledge, and a fuller account in the Report of the United States Deep Waterways Commission for 1896. In 1859 the investigation of lake levels was undertaken by the United States Lake Survey. Several stations were established on each lake, and at these regular observations were made, usually three times a day. From time to time stations were discontinued and others were established, and after the close of the field work of the Lake Survey the observations were, in many cases, continued by officers of the Engineer Corps in charge of harbor improvements. With reference to the present investigation, I have examined United States Lake Survey and other United States engineer records for the following stations:

On Lake Superior: Superior City, Duluth, Ontonagon, Marquette and Sault Ste. Marie.

On Lake Michigan-Huron: Chicago, Milwaukee, Grand Haven, Lockport, Sand Beach, Port Austin, Ponte aux Barques, Tawas, Escanaba, Thunder Bay.

On Lake Erie: Monroe, Rockwood, Cleveland, Ashtabula, Erie, Buffalo.

On Lake Ontario: Port Dalhousie, Niagara, Charlotte, Oswego, Sacketts Harbor.

These records are for the most part published in the form of monthly means, but the individual observations are preserved in the Engineer Office at Washington, and these have been made accessible to me through the courtesy of Gen. William P. Craighill, Chief of Engineers. By the Canadian Department of Railways and Canals I have been enabled to make use of a long series of observations at Port Colborne, on Lake Erie, the head of the Wel-

land canal; observations at Toronto, on Lake Ontario, have been furnished me by the city engineer, and observations at Collingwood, on Lake Huron, by Mr. Frank Moberly.

Benches.—As gages at the water side are subject to various accidents, it is rarely possible to maintain their zeros for long periods at a constant level, and unless they are connected by leveling with bench marks of a permanent character their records have little value for purposes of comparison. Previous to 1871 such connection with benches was not made by the United States Lake Survey, or if made, the records are lost. There were, however, certain stations, notably Chicago, Milwaukee, Cleveland, Port Colborne, Buffalo, Charlotte and Oswego, at which this matter had received attention. The structures at Chicago on which the early bench marks were made are thought to have afterwards settled.* At Milwaukee the early bench marks no longer exist, and although there is reason to believe that other benches were substituted with care, my researches have not discovered a satisfactory record. The same remark applies to Buffalo; and the record of the original bench at Charlotte has been lost. At Port Colborne and Oswego the zero of gages are permanent structures, which have probably suffered no change; and at Cleveland, although the oldest benches no longer exist, it is believed that the record of transfer is complete and satisfactory.

In 1870 Gen. C. B. Comstock was placed in charge of the United States Lake Survey, and the scientific methods introduced by him included the establishment of a complete system of benches in connection with the gages. From 1872 until the completion of the field work of the Lake Survey there was an annual inspection of the gages, and the relations of their zeros to the bench marks were

* Report on Chicago City Datum and City Bench Marks, by W. H Hedges, Chicago, 1895.

redetermined as often as seemed necessary. From 1871 to 1878 the supervision of gages and the reduction of records were in charge of Mr. O. B. Wheeler, and from 1879 to 1882 of Mr. A. R. Flint. The results of the present investigation are largely indebted to the care and thoroughness with which these engineers performed their work.

SELECTIONS OF STATIONS AND YEARS.

Under the general method outlined above, the first step was the selection of suitable pairs of stations on the shores of the various lakes. As the geologic data indicated a tilting of the land toward the south-southwest, or, more precisely, in the direction S. 27° W., it was desirable to have each pair of stations separated by a long distance in that direction. As the hypothetic change was exceedingly slow, it was desirable to compare observations separated by the longest practicable time intervals. It was essential that the gage readings before and after the time intervals be accurately connected with the same benches. Consideration was also given to the fact that the results might be vitiated if use were made of observations taken during the prevalence of storms, when the water is sometimes driven by the wind so as to stand abnormally high on certain shores; and in order that the use of such observations might be avoided it was important to select years during which the force of the wind was daily recorded. With these considerations in view the available data were examined, and the following selection was made of stations (see fig. 99) and years:

For Lake Ontario, Charlotte and Sacketts Harbor, 1874 and 1896.

For Lake Erie, Cleveland and Port Colborne, 1858 and 1895.

For Lake Michigan–Huron, Milwaukee and Port Austin, 1876 and 1896, and Milwaukee and Escanaba, 1876 and 1896.

No comparison was undertaken for stations on Lake Superior.

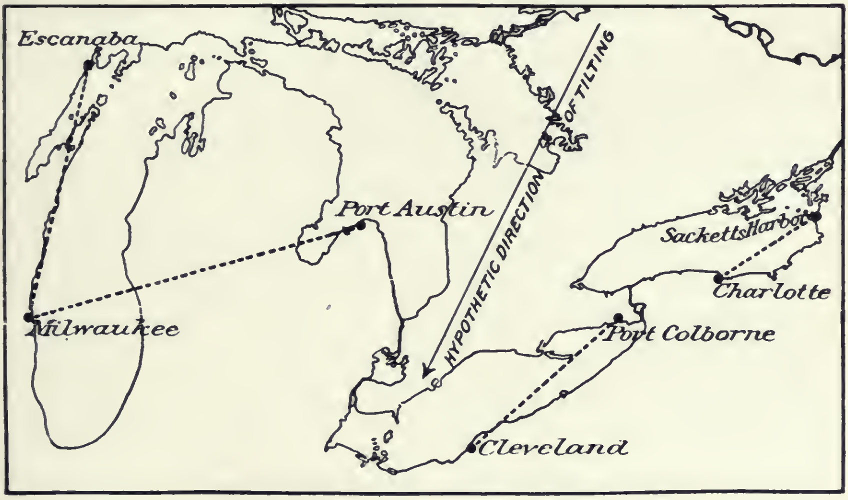


FIG. 99.—Arrangement of selected stations.

SPECIAL OBSERVATIONS IN 1896.

Certain of the selected stations are not now maintained by the United States engineers, and in order to complete the data it was necessary to make special observations. This was done in the summer of 1896, during the months of July, August, September and October. The necessary attention was also given to bench marks, and provision was made for observations of a special character at the regular engineer stations.

At Sacketts Harbor use was made of a gage which had been established for temporary purposes by Maj. W. S. Stanton, U. S. E. It was connected, by leveling, with an old bench mark, and an observer was employed. At Charlotte the relation of the gage zero to a bench mark was determined by leveling, and special series of observations were made by the observer employed by the United States engineers. At Port Austin a new gage was established and a special observer employed. At Milwaukee and Escanaba the relative heights of gages and bench marks were determined under direction of Capt. George A. Zinn, U. S. E., and special observations were made by the observers regularly employed by the United States engineers.

The "special" observations at these stations consisted of series of readings intended to eliminate the effect of the oscillations called "seiches." The equilibrium of a lake surface is disturbed not only by winds, which blow the water toward the lee shore, but by inequalities of atmospheric pressure occurring during thunderstorms and during the passage of cyclones; and the impulses thus received are not quickly dissipated, but cause a long-continued swaying of the water. In large lakes these oscillations are so enduring as to cover the interval from one disturbing impulse to another, and keep the water perpetually in motion. Near the ends of the lakes and in bays with gradually converging sides the range of oscillation may be as great as 1 foot, and it

ordinarily amounts at all lake stations to from 1 inch to 4 inches For this reason a single observation may not approximate closely to the mean level of the water, and the actual mean level can be determined only by a series of observations at short intervals. In arranging the work of 1896 the observers were instructed to record the water level every five minutes for an hour each morning and evening of all days when the wind was light; and at Sacketts Harbor, where the seiche has an exceptionally long period, the length of the series was afterwards increased.

DISCUSSION OF DATA FROM PAIRS OF STATIONS.

SACKETTS HARBOR AND CHARLOTTE.

In 1874 the zeros of gages at these stations were points marked on docks, and readings were made by means of graduated vertical rods attached to floats. They give the distance of the water surface below the gage zeros. At the time of each observation record was also made of the direction and force of the wind. The work was under the direction of the United States Lake Survey. Mr. A. Wilder was the observer at Charlotte, and Mr. Henry Metcalf at Sacketts Harbor.

The gage at Charlotte was put in place in November, 1871, and the measurements showed its zero to be 32.7 feet below a bench mark. In January, 1873, its zero was found to be 32.959 feet below the same bench mark. On May 11, 1874, it was again compared with the bench mark, and the difference was found to have increased to 33.003 feet. It is probable that this change of .044 foot was occasioned by the settling of the dock to which the gage was attached. A manuscript report dated February 3, 1875, says: "The bank is here partly of timbers and partly of earth. The earth has been washed out and has fallen away from the timber in some places." The gage at Sacketts Harbor was also found unstable. The report of an inspection in May, 1874, states that the zero of gage "has been lowered 0.555 foot;" and a report dated February 3, 1875, says: "This gage is fastened to the timbers of an old and unused dock. The instability of gages determined the selection of time for the comparison of stations. Both gages having been compared with benches in May, 1874, that at Charlotte on the 11th and that at Sacketts Harbor probably on the 14th, the computations were based on a period including these dates. Within this period selection was made of those times of observation when the wind force at both stations was less than 3 on a scale of 10. Thus treated, the observations of 54 days gave 51 comparisons.

Computation of the height of the gage zero at Sacketts Harbor, New York, above the gage zero at Charlotte, New York, in the spring of 1874.

DAY.	Hour.	GAGE READING.		Difference.
		Sacketts Harbor.	Charlotte.	
1874.		Feet.	Feet.	Feet.
April 17	9 p. m.	5.43	3.15	2.28
19	9 p. m.	5.33	3.01	2.32
22	9 p. m.	5.23	2.98	2.25
23	7 a. m.	5.16	2.80	2.36
	2 p. m.	5.18	2.78	2.40
24	7 a. m.	5.20	2.80	2.40
25	7 a. m.	5.18	2.80	2.38
	2 p. m.	5.11	2.81	2.30
27	7 a. m.	5.08	2.78	2.30
	9 p. m.	4.88	2.78	2.10
28	2 p. m.	5.13	2.87	2.26
	9 p. m.	5.06	2.88	2.18
May 3	7 a. m.	5.06	2.95	2.11
4	7 a. m.	5.43	2.95	2.48
	2 p. m.	5.09	2.94	2.15
5	9 p. m.	5.16	2.94	2.22
6	9 p. m.	5.18	2.91	2.27
7	9 p. m.	5.12	2.85	2.27
8	7 a. m.	5.06	2.87	2.19
11	9 p. m.	5.17	2.85	2.32
14	9 p. m.	5.17	2.82	2.35
15	9 p. m.	5.12	2.83	2.29
	7 a. m.	5.17	2.84	2.33
	2 p. m.	5.25	2.82	2.43
18	2 p. m.	5.13	2.82	2.31
	9 p. m.	5.18	2.83	2.35
20	7 a. m.	5.05	2.83	2.22
	2 p. m.	5.10	2.82	2.20
21	7 a. m.	5.02	2.81	2.21
22	9 p. m.	5.02	2.82	2.20
24	7 a. m.	5.12	2.95	2.17
	2 p. m.	5.08	2.92	2.16
	9 p. m.	5.08	2.91	2.17
26	9 p. m.	5.08	2.86	2.22
27	7 a. m.	5.00	2.86	2.14
	9 p. m.	5.10	2.84	2.26
28	7 a. m.	4.98	2.83	2.15
	9 p. m.	5.02	2.83	2.19

Computation of the height of the gage zero at Sacketts Harbor, New York, above the gage zero at Charlotte, New York, in the spring of 1874—(Continued).

DAY.	Hour.	Gage Reading.		Difference.
		Sacketts Harbor.	Charlotte.	
1874.		Feet.	Feet.	Feet.
May 30	7 a. m.	5.00	2.81	2.19
	9 p. m.	5.03	2.82	2.21
June 1	9 p. m.	4.97	2.82	2.15
2	7 a. m.	5.00	2.83	2.17
	9 p. m.	5.02	2.85	2.17
4	9 p. m.	5.10	2.82	2.28
5	9 p. m.	5.00	2.78	2.22
6	7 a. m.	5.00	2.78	2.22
	9 p. m.	5.09	2.79	2.30
7	7 a. m.	5.10	2.79	2.31
	2 p. m.	5.00	2.81	2.19
8	9 p. m.	4.97	2.81	2.16
9	7 a. m.	4.97	2.82	2.15
Mean				2.247 ±.008

In 1896 the gage at Charlotte was a graduated plank spiked to a pile just north of the western abutment of the Rome, Watertown and Ogdensburg railroad bridge. The readings give the distance of the water surface above the zero of the gage. At Sacketts Harbor the arrangement was similar, the gage being spiked to an unused dock. The observer at Charlotte was Mr. J. W. Preston, harbor master; at Sacketts Harbor, Mr. Wilbur S. McKee. Observations were made morning, noon and night, the morning and evening observations being extended into series whenever the water was so little agitated by waves that the position of its surface could be determined with precision. As the times selected for these periods of observation were also comparatively free from atmospheric disturbances, and therefore favorable to a general equilibrium

of lake surface, the computations were restricted to such times. In the four months of observations there were but five occasions when series were made at both stations.

Computation of the height of the gage zero at Sacketts Harbor, New York, above the gage zero at Charlotte, New York, in the summer of 1896.

DATE.	HOUR OF COMMENCING OBSERVATION.		NUMBER OF FIVE MINUTE READINGS.		MEAN OF READINGS.		DIFFERENCE.
	Sacketts Harbor.	Charlotte.	Sacketts Harbor	Charlotte.	Sacketts Harbor.	Charlotte.	Charlotte minus Sacketts Harbor.
1896.					Feet.	Feet.	
Aug. 8....	7.15 a. m.	7 a. m.	13	13	0.984	0.962	—0.022
8....	6.30 p. m.	6 p. m.	13	12	0.912	0.934	0.022
Sept. 9....	5.30 a. m.	7 a. m.	13	13	0.351	0.428	0.077
14....	5.00 p. m.	6 p. m.	13	13	0.270	0.386	0.098
Oct. 27....	8.15 a. m.	7 a. m.	45	11	—0.148	—0.048	0.100
Mean							+0.055 ±0.014

The bench at Charlotte is a mark on the upper surface of the water table of the old light-house. The walls of the building show no cracks, and there is every reason to believe the bench stable. On May 11, 1874, the zero of gage was found by Mr. E. S. Wheeler, assistant engineer United States Lake Survey, to be 33.003 feet below this bench mark. On June 30, 1896, I leveled from the zero of the present gage to the bench mark, obtaining 38.950 as the mean of two measurements. On July 11, 1897, Mr. Warner W. Gilbert obtained 38.954 feet as a mean of two measurements.

The only bench mark existing at Sacketts Harbor in 1874 and 1896 is a point on the upper outer edge of the water table at the northeast corner of the stone building known as the Masonic Temple. In May, 1874, this was determined by Mr. Wheeler to be 12.225 feet above the zero of gage. On June 28, 1896, by duplicate measurements, I found it to be 20.425 feet above the zero of

the present gage. The building bearing this mark rests on a foundation of bed rock, but nevertheless has yielded to such extent that its walls are cracked. I was informed that the cracking and repairing of the walls took place some years previous to 1874, and regard it as probable that there has been no change since that date in the height of the bench mark.

These several data are combined in the following table:

Computation of the height of the bench mark at Charlotte, New York, above the bench mark at Sacketts Harbor, New York, in 1874 *and* 1896.

	1874. Feet.	1896. Feet.
Charlotte bench mark above Charlotte gage zero	+33.003	+38.950
Charlotte gage zero above Sacketts Harbor gage zero	— 2.247	— 0.055
Sacketts Harbor gage zero above Sacketts Harbor bench mark	—12.225	—20,425
Sum of above = Charlotte bench mark above Sacketts Harbor bench mark	+18.531	+18.470
Difference	—0.061	

The results of the computations indicate that the height of the Charlotte bench mark above the Sacketts Harbor bench mark has diminished in twenty-two years to the extent of 0.061 foot. This quantity is the algebraic sum of six other quantities, two measurements through water leveling and four measurements by the engineer's level. The probable errors of the water levelings are ±0.008 and ±0.014 foot; the probable errors of my own instrumental levelings were each ±0.01 foot. Assigning the same precision to the earlier levelings, we obtain for the resulting quantity (0.061 foot) a probable error of about ±.03 foot.

This probable error attempts to express only such deviations from accuracy as are exhibited by the discordance of observations

it does not include errors of the class called constant. The result may be vitiated by the instability of either bench or by river freshets in 1874, and there are qualifications related to tides and cyclonic gradient.

The data at Sacketts Harbor are not subject to errors from stream floods. The gages at Charlotte were on the bank of the Genesee River near its mouth. The channel is deep, and at ordinary river stages the current is so gentle that river level and lake level are the same, but in time of flood the river level is somewhat higher. In 1896 no flood periods were included, but the records for 1874 are not full enough to insure freedom from flood influences. If the Charlotte data include errors due to that cause, their correction would increase the computed change of relative height.

The tides of the Great Lakes are so small as to be masked by the seiches, but they are nevertheless of sufficient magnitude to affect an investigation of this sort. Lieut. Col. J. D. Graham determined a lunar tide of Lake Michigan at Chicago amounting to 1¾ inches and a spring tide amounting to 3½ inches.* Gen. C. B. Comstock determined a lunar tide of Lake Michigan at Milwaukee of 1 inch and a solar tide of one-half inch; and a tide of 1½ inches was found at the west end of Lake Superior.† The tides of Lake Ontario have not been investigated, and therefore a correction for them can not be applied. It would be quite possible to eliminate their effect by making the periods of observation include complete tidal cycles; but the local conditions gave greater importance to other criteria for the selection of times. An inspection of dates with reference to tidal cycles shows that the observations are so distributed that the influence of tide can not be great.

A complete comparative discussion of lake levels should also take account of differences of atmospheric pressure. It is evident that

*Ann. Rept. Chief of Engineers, U. S. A., for 1860, p. 296.

†Ann. Rept. Chief of Engineers, U.S.A., for 1872, pp. 1033, 1035, 1040; 1875, pp. 1173, 1192, 1194.

in a condition of equilibrium the level water surface must be deformed by local inequalities of atmospheric pressure, and the effect of pressure differences of course coexists with inequalities due to other causes. In planning these computations the intention was to apply corrections for barometric gradient, but this intention was afterwards relinquished because of the difficulty of properly discussing the available barometric data. Such examination as was given to the subject led to the opinion that during the stormless periods selected for the comparison of gage readings the error arising from the neglect of the pressure correction is small.

PORT COLBORNE AND CLEVELAND.

The character of the gage used at Cleveland in 1858 is not described in the records I have seen. Neither is the name of the observer given, but various circumstances indicate that the readings were made either by Col. Charles Whittlesey or under his immediate direction. The readings give the distance of the water surface below the high-water level of 1838, and that level was adopted by the United States Lake Survey as the plane of reference for all observations on Lake Erie. At Port Colborne the upper sill of Lock No. 27 of the Welland Canal was the zero of measurement, and the measurement was made by the lock master, Mr. John McGillivray, by thrusting a graduated pole into the water until the end rested on the lock sill. As the reference point at Cleveland was above the water surface and that at Port Colborne below, their difference in height is obtained by adding the two readings. Most of the observations at Cleveland were made at 8 a. m. and the observations at Port Colborne at noon. At Port Colborne the direction of the wind was recorded; at Cleveland, the direction and force. I do not know the scale of force employed, but the record

numbers range from 0 to 5. All observations at both stations were rejected when the wind force at Cleveland was recorded as greater than 1.

The gage zero used at Cleveland in 1895 was the upper edge of a cleat nailed to a plank forming one wall of a well in a wharf. From this the observer measured to the water surface in the well with a graduated rod. The gage zero was set at the level of high water in 1838, which is mentioned in the records as "the plane of reference." Three observations were made daily, at 7 a. m., 1 p. m. and 7 p. m., the work being under the direction of the United States Engineers. At Port Colborne observation was made by means of a float connected through a chain with a counterpoise, and was therefore indirect; but the readings were checked by occasional observations with a pole, after the method of 1858. An index on the counterpoise was so adjusted as to indicate on a scale the depth of water on the lock sill. I inspected the gage in 1896, finding it in close adjustment, except that an error in either direction of a fraction of an inch might arise from friction. The observer in 1895 was Mr. John Henshaw. In the following table the readings at Port Colborne, which were recorded in feet and inches, have been converted to feet and hundredths. The record of wind at the two stations was the same as in 1858, and there were also available the wind and pressure observations of the United States Weather Bureau. From an inspection of these data three periods were selected for comparison: June 28 to July 3, July 18 to 28, and August 3 to 18. These periods are so related to the tidal cycle as nearly to eliminate tidal error.

Computation of the height of the "plane reference" at Cleveland, Ohio, above the sill of Lock No. 27 of the Welland Canal at Port Colborne, Ontario, in 1858, and 1895.

DATE.	Reading at Cleveland.		Reading at Port Colborne.		Sum.		DATE.	Readings at Cleveland.				Reading at Port Colborne.	Sum.
								7 a. m	1 p. m.	7 p. m.	Mean.		
1858.	Ft.	in.	Ft.	in.	Ft.	in.	1895.	Feet.	Feet.	Feet.	Feet.	Feet	Feet.
Aug. 20	0	9.0	14	7	15	4.0	June 28	......	3.30	3.50	3.40	10.92	14.32
24	0	8.0	14	6	15	2.0	29	3.55	3.50	3.53	3.53	10.75	14.28
25	0	8.5	14	6	15	2.5	30	3.55	3.50	3.53	3.53	11.08	14.61
28	0	5.0	14	0	14	5.0	July 1	3.30	3.40	3.50	3.40	10.75	14.15
31	0	8.0	14	3	14	11.0	2	3.47	3.45	3.55	3.49	10.83	14.32
Sept. 1	0	7.2	14	4	14	11.2	3	3.57	3.60	......	3.58	10.92	14.50
3	0	8.0	14	0	14	8.0	18	3.57	3.80	3.83	3.73	11.00	14.73
6	0	9.5	13	11	14	8.2	19	3.85	3.50	3.70	3.68	10.75	14.43
9	0	9.4	14	1	14	10.4	20	3.80	3.68	3.53	3.67	11.25	14.92
12	0	8.7	14	0	14	8.7	21	3.33	3.87	3.63	3.61	11.00	14.61
14	0	10.7	13	8	14	6.7	22	3.90	3.50	3.60	3.67	10.75	14.42
15	0	6.0	13	11	14	5.0	23	3.60	3.70	3.70	3.67	10.83	14.50
16	0	2.3	13	9	13	11.3	24	3.68	3.60	3.70	3.66	10.83	14.49
18	0	6.7	14	3	14	9.7	25	3.72	3.73	3.82	3.76	10.67	14.43
20	0	9.3	14	0	14	9.3	26	3.70	3.73	3.63	3.69	11.00	14.69
23	1	0.8	13	11	14	11.8	27	3.75	3.70	3.32	3.59	10.92	14.51
24	1	1.5	13	5	14	6.5	28	3.50	3.43	3.80	3.58	10.75	14.33
25	1	0.9	14	0	15	0.9	Aug. 3	......	3.79	3.80	3.80	11.00	14.80
27	1	1.8	14	2	15	3.8	4	3.80	3.73	3.73	3.75	10.75	14.50
30	1	2.5	14	5	15	7.5	5	3.73	3.68	3.68	3.70	10.58	14.28
Oct. 4	1	1.6	14	0	15	1.6	6	3.90	3.73	3.70	3.78	11.33	15.11
10	1	3.0	13	10	15	1.0	7	3.93	3.95	3.76	3.83	11.75	15.58
11	1	4.0	13	6	14	10.0	8	3.75	3.60	3.80	3.72	10.67	14.39
14	1	2.2	14	3	15	5.2	9	3.72	3.70	3.59	3.67	10.83	14.50
15	0	11.0	14	3	15	2.0	10	3.90	3.75	3.70	3.78	10.75	14.53
16	0	10.5	14	5	15	3.5	11	3.80	3.50	3.64	3.65	10.67	14.32
18	1	5.0	14	2	15	7.0	12	3.54	3.78	3.68	3.67	11.00	14.67

Computation of the height of the "plane reference" at Cleveland, Ohio, etc. (Concluded).

DATE.		Reading at Cleveland.		Reading at Port Colborne.		Sum.	
1858.		Ft.	in.	Ft.	in.	Ft.	in.
Oct.	19..........	1	4.9	13	5	14	9.9
	20..........	1	2.0	13	3	14	5.0
	21..........	1	4.7	13	2	14	6.7
	22..........	1	4.8	13	7	14	11.8
	25..........	1	1.8	12	5	13	6.8
	26..........	1	4.4	12	7	13	11.4
	27..........	1	4.9	12	7	13	11.9
	28..........	1	4.3	12	11	14	3.3
	30..........	1	6.1	13	3	14	9.1
Mean (in feet)................						14.800 ±.057	

DATE.		Readings at Cleveland.				Reading at Port Colborne.	Sum.
		7 a. m.	1 p. m.	7 p. m.	Mean.		
1895.		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Aug.	13..........	3.60	8.67	3.60	3.62	10.83	14.45
	14..........	3.68	3.65	3.70	3.68	11.00	14.68
	15..........	3.61	3.72	3.65	3.66	11.00	14.66
	16..........	3.52	3.59	3.67	3.59	10.83	14.42
	17..........	3.70	3.68	3.70	3.69	10.75	14.44
	18..........	3.80	3.83	3.70	3.78	11.17	14.95
....							14.561 (±.022)

Height of Cleveland plane of reference above Port Colborne lock-sill—

1858	14.800	±.057
1895	14.561	±.022
Difference..	—0.239	±.06

The zero of gage at Port Colborne, being submerged masonry, is of unquestioned stability. The canal was constructed in 1833, and if any settling followed construction it was doubtless complete before 1858; but the appearance of the masonry above the water gives no suggestion of yielding.

The earlier work at Cleveland was connected with several bench marks, all of which have been destroyed, but before the disappearance of the last one the datum was transferred by leveling to other points. The chain on which the record depends is as follows:

1. "Top of coping of the northeast wall of the Ohio Canal lock where it joins the river." The high water of 1838 was directly compared with this bench, and Whittlesey states that it is 6.30 feet above that high water plane.* As the observations in 1858 were made near the lock, and as Whittlesey, who reports them, was a civil engineer whose writings show that he appreciated the importance of precise bench marks, it is probable that the observations were properly connected with the bench. Explicit statement, however, is lacking; the record merely refers the lake level to the high water of 1838. The bench was destroyed in 1877 or 1878.

2. "Cross on water table, northeast corner of Johnson House block, southwest corner of Front and East River streets." On June 15, 1875 (as shown by manuscript records in the office of the Chief of Engineers, U. S. A.), Assistant Engineer T. W. Wright, United States Lake Survey, leveled from this bench mark to the canal lock coping (1), finding the difference (1 above 2) to be 3.67 feet. This bench mark is still in existence. The walls of the building are cracked in such manner as to indicate some settling of the northeast corner, and the broad flagstone on which the bench is marked stands (in 1897) 0.04 foot lower than the next stone of the water table toward the west. As the lower stone supports part of

* Canadian Naturalist, Vol. VII, 1875, p. 412.

the building and the higher stone carries no load, the latter may be assumed to show the original level of the former. It is impossible to say whether this settling affects the record of water levels. The building was erected in 1842, and is, therefore, 55 years old; it was 33 years old in 1875 when the datum of levels was transferred to it. The datum remained with it eighteen years, until 1893. If settling has progressed at a uniform rate, the datum was affected 0.013 foot, but it is equally possible that the settling belonged to the early history of the building, and that a condition of practical stability was reached prior to 1875.

3. "Bottom of west angle iron, on bottom of north longitudinal plate girder, middle of first full-depth bent, close to stone pier, new L. S. & M. S. R. R. drawbridge, now [1893] being finished." As the bridge is symmetric and reversible, this description applies to two different points, but measurement shows that they have the same height. It was copied from manuscript records in the United States Engineer's office at Cleveland, courteously placed at my service by Col. Jared A. Smith. The records show that in June, 1893, the bridge bench (3) was connected by leveling with the Johnson House bench (2) and also with the gage zero, and that the gage zero was checked by the bridge in 1896 and found correct. The gage readings in 1895 (used in our computations) are thus referred to the bridge bench. The height of the bridge bench is given as 4.34 feet above the "plane of reference," and by implication as 1.71 feet above the Johnson House bench (2). The drawbridge rests on a stone pier many years older than the present bridge, and there can be little question of its stability.

In these records of bench marks and levelings in Cleveland there is certainly much to be desired, but the presumption is, nevertheless, in favor of good work.

It appears from the computation that the ground at Port Colborne has risen, as compared to the ground at Cleveland, 0.239 foot, or about $2\frac{7}{8}$ inches in thirty-seven years. The probable error of this measurement, as indicated by the discordance of gage data, is three-fourths of an inch.

As a check upon this result, a third computation was made from gage readings in the summer of 1872, a year in which the gage zero at Cleveland was connected with the canal-lock bench mark by instrumental leveling. That computation gives for the height of the plane of reference at Cleveland above the lock sill at Port Colborne 14.714 feet. If we assume a gradual change from 1858 to 1895, and interpolate between 14.800 feet, the determination for 1858, and 14.561, the determination for 1895, we obtain for the summer of 1872 the value 14.710 feet, which differs from the result of that year's observations by only 0.004 foot. The observations on Lake Erie thus accord well with the theory of a progressive southward tilting of the land.

The Port Colborne gage is not so related to streams as to subject its readings to error from floods. The Cleveland gage, like the Charlotte, is on a river estuary, and the readings are subject to influence by floods. The records include no systematic account of the condition of the river, and it is, therefore, possible that some of the observations were made when the river level was above the lake level.

PORT AUSTIN AND MILWAUKEE.

At each of these stations automatic gages were maintained for several years, and their tracings give the height of water level with an amount of detail permitting the complete elimination of seiches and tides; but there was, unfortunately, some uncertainty as to the position of the zeros, and the danger of thus introducing constant errors led me to avoid the automatic records and choose times when

other gages were employed. The earlier period selected for the comparison was the summer of 1876, and the gages then used were floats, carrying graduated vertical rods. The force and direction of the wind were recorded at Port Austin by the gage observer, and at Milwaukee by the United States Weather Bureau. From an inspection of these records, together with the Weather Bureau records of barometric gradient, selection was made of the periods July 11 to 19 and August 16 to 24, excepting only certain hours when the force of the local wind was recorded as greater than 3 in a scale of 10. This gave 46 separate comparisons, from which the difference in height of the gage zeros was computed. The chosen periods are well disposed with reference to tides. The readings at Milwaukee were made at 7 a. m., 1 p. m. and 6 p. m. by Mr. John McCabe; at Port Austin the hours were 7 a. m, 2 p. m. and 9 p. m., and the observer was Mr. J. W. Kimball. In the computations the midday observations, though one hour apart, and the evening observations, though three hours apart, were treated as simultaneous.

Computation of height of gage zero at Port Austin, Michigan, above gage zero at Milwaukee, Wisconsin, in the summer of 1876.

DATE.	Readings at Milwaukee.			Readings at Port Austin.			Differences.		
	7 a. m.	1 p. m.	6 p. m.	7 a. m.	2 p. m.	9 p. m.			
1876.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
July 11	2.17	2.23	2.12	7.22	7.31	7.47	5.05	5.08	5.35
12	2.12	2.03	2.26	7.54	7.25	7.22	5.42	5.22	5.06
13	2.20	2.05	2.35	7.35	7.37	7.35	5.15	5.32	5.00
14	1.95	2.12	2.10	7.50	7.41	7.30	5.55	5.29	5.20
15	2.16	2.15	2.06	7.33	7.35	7.30	5.17	5.20	5.24
16	2.13	2.12	2.11	7.34	7.25	7.40	5.21	5.13	5.29
17	2.15	2.20	2.21	7.37	7.37	7.30	5.22	5.17	5.09
18	2.20	2.07	2.20	7.21	7.25	7.28	5.01	5.18	5.08
19	2.18	....	....	7.34	....	....	5.16	....	....
Aug. 16	2.29	....	2.20	7.50	....	7.35	5.21	....	5.15
17	2.19	....	2.21	7.33	....	7.50	5.14	....	5.29
18	2.23	2.02	2.27	7.50	7.35	7.40	5.27	5.33	5.13
19	....	2.22	....	....	7.45	....	....	5.23	....
20	....	2.18	2.23	....	7.62	7.37	....	5.44	5.14
21	2.25	2.20	2.24	7.41	7.34	7.37	5.16	5.14	5.13
22	2.32	2.18	2.33	7.38	7.51	7.40	5.06	5.33	5.07
23	2.26	1.91	2.10	7.38	7.60	7.59	5.12	5.69	5.49
24	2.25	....	2.42	7.49	....	7.49	5.24	....	5.07
Mean									5.210 ±.013

In 1896 the gage at Milwaukee consisted of a graduated rod held in the observer's hand in measuring down to the water from a fixed point or zero. At Port Austin a board, carrying a graduated scale, was spiked to the side of a timber crib, and the position of the water surface on the scale was noted by the observer. At each of these stations a series of 12 observations, at five minute intervals, was made every morning and evening when the surface of the water was nearly smooth. The mean of a series was afterwards treated as one observation, and the computation was based on the simultaneous pairs of observations—53 in number. The selection of times was thus determined by conditions favorable for the elimination of seiches, but it appears by inspection that tidal influences also are very nearly eliminated. The observers were: At Milwaukee, Mr. John McCabe; at Port Austin, Mr. John P. Smith.

As the zero at Milwaukee was above the water, and the zero at Port Austin below, the sum of the readings gives the height of one zero above the other.

Computation of height of gage zero at Milwaukee, Wisconsin, above gage zero at Port Austin, Michigan, in the summer of 1896.

DATE.	Time.	Readings (Means of Series).		Sum.
		Milwaukee.	Port Austin.	
1896.		Feet.	Feet.	Feet.
July 20	A. M.	5.528	1.271	6.799
24	A. M.	5.483	1.333	6.816
28	A. M.	5.703	1.385	7.088
29	A. M.	5.470	1.354	6.824
	P. M.	5.560	1.375	6.935
Aug. 1	A. M.	5.436	1.297	6.733
2	P. M.	5.620	1.425	7.045
7	P. M.	5.447	1.420	6.867
9	A. M.	5.519	1.448	6.967
11	A. M.	5.575	1.433	7.008
14	A. M.	5.338	1.455	6.793
20	A. M.	5.587	1.340	6.927
20	P. M.	5.571	1.406	6.977
21	A. M.	5.558	1.330	6.888
	P. M.	5.588	1.391	6.979
22	A. M.	5.505	1.259	6.764
	P. M.	5.540	1.229	6.769
24	P. M.	5.595	1.375	6.970
25	A. M.	5.721	1.221	6.942
25	P. M.	5.792	1.268	7.060
28	P. M.	5.721	1.279	7.000
30	P. M.	5.797	1.239	7.036
Sept. 1	P. M.	5.725	1.259	6.984
2	P. M.	5.748	1.203	6.951
4	P. M.	5.720	1.248	6.968
5	P. M.	5.515	1.134	6.649
7	P. M.	5.739	1.275	7.014
8	A. M.	5.649	1.203	6.852
	P. M.	5.595	1.139	6.734
9	P. M.	5.585	1.077	6.662
14	A. M.	5.584	1.208	6.792
15	A. M.	5.560	1.181	6.741
20	P. M.	5.892	1.281	7.173
23	A. M.	5.791	1.307	7.098
25	A. M.	5.932	0.803	6.735
28	P. M.	5.755	1.167	6.922
29	A. M.	5.615	1.013	6.628

Computation of height of gage zero at Milwaukee, Wisconsin, above gage zero at Port Austin, Michigan, in the summer of 1896—(Continued.)

DATE.	Time.	Readings (Means of Series).		Sum.
		Milwaukee.	Port Austin.	
1896.		Feet.	Feet.	Feet.
Oct. 2	A. M.	5.566	1.250	6.816
3	A. M.	5.594	1.465	7.059
	P. M.	5.574	1.186	6.760
4	P. M.	5.632	1.101	6.733
5	P. M.	5.705	1.085	6.790
10	P. M.	5.506	0.889	6.395
15	A. M.	5.784	0.769	6.553
17	A. M.	5.642	1.444	7.086
18	A. M.	5.720	1.398	7.118
19	A. M.	5.846	1.215	7.061
22	A. M.	6.182	1.212	7.394
25	A. M.	6.139	0.800	6.939
26	P. M.	5.960	0.858	6.818
27	A. M.	5.918	0.750	6.668
	P. M.	5.802	0.722	6.531
29	A. M.	5.864	0.724	6.588
Mean				6.875 ± .019

Milwaukee is well provided with engineer bench marks, and it is probable that thorough research would establish the connection of the gage zeros at each epoch with several of the bench marks; but after inspection of the data readily accessible, I thought it best to make use of only one bench, that called the "check point." This consists of the top of a copper bolt leaded into the north side of the center pier of the swing bridge over the river between Chestnut and Division streets. The gage observer is required at stated intervals to check the stability of the zero of his gage by means of this check point. Using two rods, with the aid of an assistant he makes a series of simultaneous measurements from the check point

and from the gage zero down to the water level, and from these measurements the relation of the gage zero to the check point is determined. Their relation has also been determined by means of the engineer's level at various times, and was so determined on August 8, 1876, by Assistant Engineer L. L. Wheeler, who found the check point 0.843 foot above the gage zero. In 1896 the check observations by the observer were very thorough, series of twenty simultaneous readings being made every fortnight, and from five of these series the relation of the two points is computed as follows:

Computation of height of Milwaukee check point above Milwaukee zero of gage in the summer of 1896.

	Feet.
July 12 (mean of twenty comparisons by simultaneous readings)	1.203
July 26	1.212
August 14	1.200
August 28	1.203
September 16	1.206
Mean	1.205
	± .002

In response to a letter of inquiry as to the stability of the Milwaukee check point, Capt. George A. Zinn, United States engineer in charge of harbor improvements, writes as follows:

The Chestnut Street Bridge, on the center pier of which the check point is established, was built in 1872.

Mr. G. H. Benzenberg, city engineer, states that the pier rests on a pile foundation; that to his knowledge the drawbridge has never been releveled since put in place, and that if any appreciable settlement had taken place in the center pier it would have interfered with the operating of the swing bridge. He stated positively that no settlement had occurred.

The principal bench mark used in 1876 at Port Austin, called the Wisner bench mark, was a copper bolt leaded into bed rock; but in 1896 I was unable to find it, and, as at Milwaukee, I had recourse to a bench mark originally established and used as a check point. It is the top of an iron bolt driven into a vertical face of bed-rock on the west side of a promontory opposite the residence of Mr. J. W. Kimball. In July, 1875, and October, 1876, Assistant Engineer T. W. Wright found the check point 7.424 feet below the Wisner bench mark; in June, 1896, I found the gage zero 5.125 feet below the check point, this quantity being the mean of two measurements.

Manuscript records in the archives of the Lake survey state that the Port Austin gage zero was originally placed on a level with the Wisner bench mark, but that in July, 1875, it was 0.003 foot too low, and that on October 18, 1876, it was 0.040 foot too low, having settled during the interval. As the observations used fall within this interval, it was necessary to make some assumption in regard to this settling, and the assumption made was that it had been at uniform rate through the whole period. The correction interpolated for the time of observation was 0.034 foot. Combining this correction with data from leveling in 1875 and 1876, I obtained as the height of the gage zero above the check point in July and August, 1876, 7.460 feet. The various data thus described are combined in the following table:

Computation of height of Milwaukee check point above Port Austin check point in the summers of 1876 *and* 1896.

	1876. Feet.	1896. Feet.
Milwaukee check point above Milwaukee gage zero	0.843	1.205
Milwaukee gage zero above Port Austin gage zero	—5.210	6.875
Port Austin gage zero above Port Austin check point	7.460	—5.125
Sum of above=Milwaukee check point above Port Austin check point	3.093	2.955
Difference	—0.138	

This result indicates that the ground at Milwaukee, as compared to the ground at Port Austin, has subsided 0.138 foot in the twenty years from 1876 to 1896. It is the algebraic sum of six measurements, of which three are levelings by water surface and three by the engineer's level. The probable errors of the water-level measurements are ±0.019, ±0.013, and ±0.002. The probable errors of the Port Austin levelings in 1896, as indicated by the discordance of two independent results, is ±0.008. If the probable error of each of the other measurements was ±0.010, the probable error of the result is less than ±.03 foot. There is also an uncertainty arising from the possibility that the stone pier to which the Milwaukee check mark is attached has settled, another uncertainty due to the possibility of river floods, and a third involved in the assumption that the settling of the Port Austin gage zero in 1876 was at a uniform rate. If all the settling of the Port Austin zero took place before the period of observation, the assumption makes the result too large by 0.006 foot; if all the settling took place after the observations, the assumption makes the result too small by 0.031 foot. The Port Austin record is free from stream-flood influences, but the Milwaukee gage station is on a narrow estuary, like the stations at Charlotte and Cleveland.

ESCANABA AND MILWAUKEE.

In comparing Escanaba with Milwaukee the same general periods of observation were employed as in comparing Port Austin with Milwaukee, but the individual days, though selected in the same manner, were in part different. Fifty-one separate comparisons were made in 1876, and 52 in 1896. The selection of times was controlled by conditions favorable for the elimination of seiches, but the combination of days chosen was found to approximately eliminate tidal effects also.

The observations at Escanaba in 1876 were conducted in the same manner as at Milwaukee and Port Austin, the hours being 7 a. m., 2 p. m., and 9 p. m., and the observer Mr. George Preston. In 1896 the system was the same as at Milwaukee, the observer being Mr. Clinton B. Oliver. The following tables give the computations for the two years:

Computation of height of gage zero at Milwaukee, Wisconsin, above gage zero at Escanaba, Michigan, in the summer of 1876.

DATE.	Readings at Escanaba.			Readings at Milwaukee.			Differences.		
	7 a. m.	2 p. m.	9 p m.	7 a. m.	1 p. m.	6 p. m.			
1876.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet
July 11	1.86	1.90	1.78	2.17	2.23	2.12	0.31	0.33	0.34
12	1.90	1.75	1.78	2.12	2.03	2.16	.22	.28	.38
13	2.00	2.07	1.95	2.20	2.05	2.35	.20	—.02	.40
14	2.10	2.15	2.05	1.95	2.12	2.10	—.15	—.03	.05
15	1.96	1.95	2.00	2.16	2.15	2.06	.20	.20	.06
16	1.90	1.95	1.85	2.13	2.12	2.11	.23	.17	.26
17	1.89	1.80	1.85	2.15	2.20	2.21	.26	.40	.36
18	2.05	1.85	1.95	2.20	2.07	2.20	.15	.22	.25
19	1.75	....	....	2.18	....	....	.43	....	....
Aug. 16	2.07	1.94	1.90	2.29	2.30	2.20	.22	.36	.30
17	2.00	1.95	1.95	2.19	2.13	2.21	.19	.18	.26
18	1.70	1.93	2.00	2.23	2.02	2.27	.53	.09	.27
19	1.78	2.00	....	2.13	2.22	....	.35	.22	....
20	1.95	1.90	1.85	2.23	2.18	2.23	.28	.28	.38
21	1.85	2.05	2.10	2.25	2.20	2.24	.40	.15	.14
22	1.83	2.05	1.90	2.32	2.18	2.33	.49	.13	.43
23	1.91	1.83	1.75	2.26	1.91	2.10	.35	.08	.35
24	1.95	1.85	1.90	2.25	2.10	2.42	.30	.25	.52
Mean									0.255 ±.012

Computation of height of gage zero at Escanaba, Michigan, above gage zero at Milwaukee, Wisconsin, in the summer of 1896.

DATE.	Time.	Readings (Means of Series).		Difference.
		Milwaukee.	Escanaba.	
1896.		Feet.	Feet.	Feet.
July 2	P. M.	5,465	5,917	0.452
7	A. M.	5,434	5,907	.473
8	A. M.	5,505	5,920	.415
9	A. M.	5,348	5,837	.489
	P. M.	5,356	5,765	.409
10	A. M.	5,442	5,771	.329
	P. M.	5,567	5,694	.127
11	P. M.	5,576	5,771	.195
13	A. M.	5,411	5,869	.458
	P. M.	5,493	5,776	.283
14	A. M.	5,574	5,750	.176
17	A. M.	5,431	5,865	.434
19	A. M.	5,524	6,007	.483
	P. M.	5,496	5,887	.391
20	A. M.	5,528	5,803	.275
21	A. M.	5,573	5,973	.400
23	A. M.	5,645	5,908	.263
25	A. M.	5,601	5,856	.255
28	A. M.	5,703	5,857	.154
31	A. M.	5,446	5,938	.492
Aug. 1	P. M.	5,360	5,859	.499
4	A. M.	5,654	5,912	.258
8	P. M.	5,347	5,954	.607
9	A. M.	5,519	5,658	.139
10	P. M.	5,328	5,546	.218
13	A. M.	5,273	5,616	.343
	P. M.	5,378	5,752	.374
14	A. M.	5,338	5,670	.332
15	A. M.	5,360	5,730	.370
	P. M.	5,402	5,710	.308
19	A. M.	5,414	5,878	.464
21	A. M.	5,558	5,935	.377
	P. M.	5,588	5,872	.284
22	A. M.	5,505	5,698	.183

Computation of height of gage zero at Escanaba, Michigan, above gage zero at Milwaukee, Wisconsin, etc.—(Continued).

DATE.	Time.	Readings (Means of Series).		Difference.
		Milwaukee.	Escanaba.	
1896.		Feet.	Feet.	Feet.
Sept. 4	A. M.	5,734	6,028	.294
13	P. M.	5,452	5,848	.396
14	A. M.	5,584	5,762	.178
16	A. M.	5,500	5,937	.437
18	A. M.	5,701	6,047	.346
26	A. M.	5,914	6,187	.273
28	P. M.	5.755	6,224	.469
29	P. M.	5,510	6,133	.623
Oct. 7	A. M.	5,514	6,164	.650
14	A. M.	5,731	6,270	.539
	P. M.	5,813	6,157	.344
17	P. M.	5,622	6,160	.538
19	A. M.	5,846	6,287	.441
20	A. M.	5,857	6,346	.489
22	A. M.	6,182	6,539	.357
	P. M.	6,148	6,540	.392
26	A. M.	6,080	6,471	.391
	P. M.	5,980	6,544	.564
Mean				0.374 ±.012

The bench employed at Milwaukee has already been described. At Escanaba there were three bench marks in good standing, as follows: No. 1, the top of the water sill on the southeast corner of the Adler building, northwest corner of Ludington street and Druseman avenue; No. 2, the top of the water sill of the Escanaba light-house at the north side of front door, against the brick wall; No. 3 is described in 1876 as the "center of a copper bolt set horizontally in the foundation of the light-house, west side, north corner, 3 feet north from steps." In a description by Capt. George A. Zinn, dated June 30, 1896, the top of the bolt is specified. I am informed by Mr. Clinton B. Oliver, the gage observer, that the

diameter of the bolt is three-eighths inch. The relative heights of two or more of these bench marks have been determined in at least six different years, the measurements being made independently with the engineer's level. It is advantageous to compare these measurements, not only to learn what confidence is to be reposed in the individual benches, but for the sake of whatever light may be cast on the general precision of such data.

Comparison of Escanaba bench marks with one another.

YEAR.	ABOVE ZERO OF GAGE.			DIFFERENCE BETWEEN BENCH MARKS.			DEVIATION FROM MEAN.		
	No. 1.	No. 2.	No. 3.	1—2.	1—3.	2—3.	1—2.	1—3.	2—3.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1874	4.135	—2.100	....	*a*6.235	....	....	....	....	....
1875	7.859	2.382	....	5.477	....	....	+0.003	....	....
1876	7.874	2.409	1.392	5.465	6.482	1.017	— .009	+0.002	+0.005
1880	7.878	2.402	1.035	5.476	*a*6.843	*a*1.367	+ .002	....	....
1887	7.753	2.285	1.280	5.468	6.473	1.005	— .006	— .011	— .007
1896	7.780	2.297	1.283	5.483	6.497	1.014	+ .009	+ .013	+ .002
Mean	....	....	....	5.474	6.484	1.012	....	....	....

a Not used in computing means.

In this table the reading of the height of bench mark No. 3 in 1876 is corrected for the distance between center and top of bolt. In the first division of the table the benches are referred to zero of gage, but as the gage was not constant in position these numbers differ widely from year to year. In the second division the relations of the gages one to another are given, being deduced by subtraction from the numbers of the first division, and these figures are more accordant. It appears, however, that the difference between benches 1 and 2 in 1874 departs widely from differences found in other years, and it is therefore probable that a blunder of measurement or record was made in that year. It appears further, by inspection, that the difference between benches 1 and 3 and the difference between benches 2 and 3 in 1880 are not in accord with the differences found in other years, and it is evident that some blunder was made in the measurement or record of the height of bench 3 for that year. These figures were accordingly thrown out and not used in the computation of the means. The numbers of the third division were obtained by subtracting the means from the several numbers of the second division, and they show the deviations from mean after rejecting the records showing gross errors. Inspection of the table of deviations shows that their signs are irregularly distributed, and discovers no evidence of progressive change from year to year. It is therefore probable that all three of the benches are stable, and that the deviations of the measurements from uniformity represent ordinary errors of observation. They may accordingly be used as a rough measure of the precision, barring blunders, of the instrumental leveling on which the results of this investigation largely depend. Their mean is 0.006 foot, and the computed probable error of a single measurement is ±0.008 foot. In combining various data for the comparison of Escanaba with Milwaukee, bench mark No. 1 of Escanaba was first used.

Computation of the height of Escanaba bench mark No. 1 *above Milwaukee check point in the summers of* 1876 *and* 1896.

	1876. Feet.	1896. Feet.
Escanaba bench No. 1 above Escanaba gage zero	7.874	7.780
Escanaba gage zero above Milwaukee gage zero	—0.255	.375
Milwaukee gage zero above Milwaukee check point	—0.843	—1.205
Sum of above = Escanaba bench No. 1 above Milwaukee check point......	6.776	6.949
Difference........................	+ .173	

The result indicates that the ground at Escanaba, as compared with the ground at Milwaukee, has risen 0.173 foot in twenty years. This quantity is the algebraic sum of six measurements, of which three were made through water leveling and three by instrumental leveling. The probable errors of the water levelings are ±0.012, ±0.012 and ±0.002 foot; the estimated probable error of the instrumental levelings at Milwaukee is ±0.010 foot, and of the two levelings at Escanaba each ±0.008 foot. This gives as the probable error of the result ±0.022 foot.

A similar computation, using bench mark No. 2 instead of bench mark No. 1, gives 0.155 foot instead of 0.173, and a computation based on bench mark No. 3 gives 0.156. The mean of the three results is 0.161 foot, with a probable error of ±0.022 foot. The only important uncertainties to which this result is subject, besides those indicated by the discordance of measurements, arise from the possibility of the settling of the bridge pier to which the Milwaukee check point is attached and the possibility of river floods.

DISCREPANCY NOTED BY CAPTAIN MARSHALL.

In the later work of the United States Lake Survey all determinations of lake level were referred to the high-water level of 1838, which is called the "plane of reference." That plane was directly observed by Dr. I. A. Lapham, the geologist, and with the aid of a bench mark on his house at Milwaukee was permanently recorded. For other stations on Lake Michigan-Huron its position was determined by assuming that the level of 1838 had everywhere the same height above the mean lake level as determined by long series of observations. For the determination of this plane at Escanaba use was made of observations for the period from January 1, 1860, to December 31, 1875. In 1887 Capt. W. L. Marshall, U. S. E., under whose direction the gage readings at Milwaukee and Escanaba were then made, detected a discrepancy, which he reported to the Chief of Engineers in a letter dated October 1.*

In former reports the zero of Escanaba gage has been assumed as 0.76 foot above the plane of reference, but a comparison of corrected readings at Milwaukee and Escanaba shows that the determinations of the plane of reference at Milwaukee and Escanaba vary 0.187 foot, the Escanaba plane being too high or the Milwaukee determination too low.

In the light of present knowledge it seems probable that the discrepency thus noted by Captain Marshall as an error was occasioned either wholly or in chief part by the progressive tilting of the land. This conclusion is difficult of verification, because little record survives of such checks as may have been made upon the heights of gage zeros during the period 1860–1875; but the indicated change agrees in direction, and approximately in rate, with the change deduced from the present investigation. From the middle of the period 1860–1875 to the summer of 1887 was an interval of twenty

* Ann. Rept. Chief of Engineers, U. S. A., for 1887, part 3, p. 2417.

years, equal to the interval 1876–1896 here used, and the discrepancy of 0.187 foot discovered by Captain Marshall differs from the change of 0.161 foot here deduced by a quantity little greater than the probable error ascribed to the latter determination.

SUMMARY OF RESULTS.

In the following table are assembled the numerical results as to changes in relative height of the four pairs of stations. Besides the measured changes, the table includes the periods intervening between dates of measurement and distances between the stations of each pair. The lines connecting pairs of stations have a southwesterly direction (fig. 99, op. p. 88), and it is the northeastern station of each pair that appears to have risen as compared to the other.

The results thus show a general agreement with the working hypothesis, that the latest change recorded by geologic data is still in progress. To make the comparison quantitative there should be substituted for the direct distances between stations the corresponding distances in the assumed direction of tilting, S. 27° W., and the measured results for various distances and various time intervals should be reduced to a common basis. In the third column of the table are the reduced distances, and in the sixth the reduced rates of change. Assuming the change to have a uniform rate and to be the same for all parts of the region, the measurements at the different pairs of stations give for a distance of 100 miles and a period of a century the quantities of the sixth column. The seventh column contains the probable errors of quantities in the sixth, and is based on the probable errors of the measured changes in pairs of stations:

Summary of distances, time intervals, and measurements of differential earth movements.

PAIRS OF STATIONS.	Direct distance.	Distance in direction S. 27° W.	Interval between dates of measurement.	Change in relative height.	Change per 100 miles per century.	Probable error of quantities in last column.
	Miles.	Miles.	Years.	Feet.	Feet.	Feet.
Sacketts Harbor and Charlotte	88	76	22	0.061	0.37	0.18
Port Colborne and Cleveland	158	141	37	0.239	0.46	0.11
Port Austin and Milwaukee	259	176	20	0.137	0.39	0.09
Escanaba and Milwaukee	192	186	20	0.161	0.43	0.06
Mean					0.41	....
Weighted mean					0.42	±0.044

IS THE LAND TILTING?

With the numerical results of the investigation before us we may now recur to the main subject and ask whether the evidence warrants the conclusion that a general, gradual tilting of the basin is in progress. In the discussion of the data used in comparing the several pairs of stations it has been found that, taken at their face value, they indicate a tilting in the hypothetic direction, but it has also been found impossible to resolve all doubts as to the stability of the gages and benches and the accuracy of the measurements. By reason of these doubts the result from no single pair of stations is conclusive, but when assembled they exhibit a harmony which argues strongly for their validity. As tabulated, there are four results, but these are not all independent, since observations and measurements at Milwaukee are used twice. There are, however, three results wholly independent and a fourth partly independent. To these may be added a fifth partly independent, namely, the determination of change between Port Colborne and Cleveland for the shorter period, 1872–1895. Not only do all these results indicate a change of the same sort, but they agree fairly well as to quantity. The computed change for 100 miles in a century ranges only from 0.37 to 0.46 foot, and the greatest deviation of an individual result from the mean of four is 12 per cent. This measure of harmony appeals strongly to the judgment, and is also susceptible of approximate numerical expression. If the four determinations tabulated in the sixth column are, in fact, measures of the same quantity—that is, if the tilting has been uniform throughout, as we have assumed—then the probable error of the determined value of that quantity (0.42 foot) is less than ±0.05 foot.

The most important factors tending to throw doubt on the conclusion are the possibilities of accidental change in the various benches to which the measurements are referred. The bench at

Port Austin, being a mark on bedrock, is trustworthy, and the agreement between the three benches used at Escanaba is good evidence of their stability; but the bench at Milwaukee, with which both are compared, is a pier of a bridge in daily use and may, perhaps, be slowly settling. If it is settling, the comparisons with benches at Escanaba and Port Austin may merely reveal that fact and not measure the subsidence of the land. The fact that the swing bridge on the pier has not required re-leveling is certainly favorable to the stability of the pier, especially when it is considered that a change of fully 1½ inches is to be accounted for; and there is further confirmation in the discovery of a discrepancy between Milwaukee and Escanaba by Captain Marshall, whose data are probably independent of the check mark. Of the benches on Lake Erie, the one at Port Colborne is satisfactory, but those at Cleveland may have settled at critical times, and if so their change would influence the result in the direction found. Of the benches on Lake Ontario, the one at Charlotte is eminently stable; the only practical question affects the bench at Sacketts Harbor, which is on a building that has not been wholly stable since its construction, although presumably so since the making of the bench. If the building at Sacketts Harber settled between 1874 and 1896, the effect of the lowered bench was to produce, not such a change as appears from the measurements, but one with the opposite sign.

It seems to me that the harmony of the measurements and their agreement with prediction from geologic data make so strong a case for the hypothesis of tilting that it should be accepted as a fact, despite the doubts concerning the stability of the gages.

RATE OF MOVEMENT.

The deduced mean rate of change—0.42 foot to the 100 miles in a century—depends on assumptions which are convenient rather than probable. These are: (1) that the whole region moves

together as a unit, being tilted without internal warping, and (2) that the direction of its present tilting is identical with the direction of the total change since the epoch of the Nipissing outlet of the upper lakes. What we know of the general character of earth movements gives no warrent for such assumptions of uniformity, but no better assumptions as to this region are now available. Under the law of probabilities, the close agreement of four measurements, three of which are wholly independent, gives a good status to their mean, but there are other considerations tending to weaken this status. The probable errors of the individual measurements are rather high, ranging from 14 to 50 per cent., and this suggests the possibility that the closeness of their correspondence may be accidental. It should be remembered also that at two or three stations there was reason to believe that the gage zeros were settling during the period in which the observations were made, and the results involve the doubtful assumption that the rate of settling was uniform. There is room for doubt as to the precision of the instrumental leveling; in only a few instances is the fact of duplicate measurements recorded, and single measurements are notoriously insecure. Error was doubtless admitted by ignoring the effects of barometic gradient. River floods may have introduced errors. In the absence of flood records the records of rainfall at Rochester (near Charlotte), Cleveland, and Milwaukee were compared with the gage readings, the results showing only that if flood errors are involved they must be small. There may also be personal equations of observers, especially as the gages at pairs of stations were not in every case of the same type. For all these reasons I am disposed to ascribe only a low order of precision to the deduced rate of change, and regard it as indicating the order of magnitude rather than the actual magnitude of the differential movement.

The rate of change indicated by Stuntz's observations is more rapid. As already quoted, he states that at a time when Lake Superior was exceptionally low at its outlet, it was nevertheless so high at its western extremity as to obliterate from the St. Louis River a rapid which had been visible only a few years before. This statement involves no definite measures, but it implies that the change within the memory of individuals involves feet rather than the inches deduced from the studies in the other lakes. Similar inferences may be drawn from his statement as to submerged stumps. The recorded range of water level in Lake Superior is about 5 feet, and trees would grow little if any below high-water mark. If, then, with low stage at the east end, stumps are submerged at the west, a change of 5 feet or more would seem to have occurred during the period covered by the growth of a tree and the survival of its stump. The differences between the inferences drawn from this evidence and the result based on gage readings on the other lakes is so wide as to suggest the possibility of error in the Lake Superior observations. It is certainly important that they be verified. Unfortunately I have not been able to visit the region, and the gage records accessible to me are not so connected with bench marks as to give a satisfactory basis for computation. The United States Lake Survey made observations of lake level at Superior City from 1859 to 1871, and then transferred the station to Duluth, where it was continued for two or three years. No bench mark at Duluth is described, and the only recorded bench mark at Superior City is upon a wooden structure, Johnson & Alexander's sawmill. If this bench survives, a good test could be made by renewing the gage station at Superior City. At the other end of the lake, at Sault Ste. Marie, there are authentic benches dating from 1855.

If we assume that the rate of 0.42 foot per 100 miles per century is uniform and secular, and project it backward to the time when the drainage of Lake Huron was shifted from North Bay to Port Huron, we obtain for the period since that change about 10,000 years. From studies at Niagara, Taylor has estimated the same period as between 5,000 and 10,000 years;* and the comparison indicates that the rate of modern change is of such magnitude as to accord well with the idea that it merely continues the geographic change.

It is to be hoped that eventually a better measure of the rate of tilting and a surer indication of its direction may be obtained, but even with present knowledge there is interest and profit in considering the economic and geographic consequences of the tilting.

GEOGRAPHIC CHANGES RESULTING FROM THE MOVEMENT.

Assuming that the general result of this investigation is substantially correct — that the whole lake region is being lifted on one side or depressed on the other, so that its plane is bodily canted toward the south-southwest, and that the rate of change is such that the two ends of a line 100 miles long and lying in a south-southwest direction are relatively displaced four-tenths of a foot in 100 years — certain general consequences may be stated. The waters of each lake are gradually rising on the southern and western shores or falling on the northern and eastern shores, or both. This change is not directly obvious, because masked by temporary changes due to inequalities of rainfall and evaporation and various other causes, but it affects the mean height of the lake surface. In Lake Ontario the water is advancing on all shores, the rate at any place being proportional to its distance from the isobase through the outlet

* Bull. Geol. Soc. America, Vol. IX, 1898, p. 83.

(AA, fig. 100). At Hamilton and Port Dalhousie it amounts to 6 inches in a century. The water also advances on all shores of Lake Erie, most rapidly at Toledo and Sandusky, where the change is 8 or 9 inches in a century. All about Lake Huron the water is falling, most rapidly at the north and northeast, where the distance from the Port Huron isobase (CC, fig. 100) is greatest; at Mackinac the rate is 6 inches, and at the mouth of French River 10 inches, a century. On Lake Superior the isobase of the outlet (DD, fig. 100) cuts the shore at the international boundary; the water is advancing on the American shore and sinking on the Canadian. At Duluth the advance is 6 inches, and at Heron Bay the recession is 5 inches, a century. The shores of Lake Michigan are divided by the Port Huron isobase. North of Oconto and Manistee the water is falling; south of those places it is rising, the rate at Milwaukee being 5 or 6 inches a century, and at Chicago 9 or 10 inches. Eventually, unless a dam is erected to prevent, Lake Michigan will again overflow to the Illinois River, its discharge occupying the channel carved by the outlet of a Pleistocene glacial lake. The summit in that channel is now 8 feet above the mean level of the lake, and the time before it will be overtopped (under the stated assumption as to rate of tilting) may be computed. Evidently the first water to overflow will be that of some high stage of the lake, and the discharge may at first be intermittent. Such high-water discharge will occur in 500 or 600 years. For the mean lake stage such discharge will begin in about 1,000 years, and after 1,500 years there will be no interruption. In about 2,000 years the Illinois River and the Niagara will carry equal portions of the surplus water of the Great Lakes. In 2,500 years the discharge of the Niagara will be intermittent, falling at low stages of the lake, and in 3,500 years there will be no Niagara. The basin of Lake Erie will then be tributary to Lake Huron, the current being reversed in the Detroit and St. Clair channels.

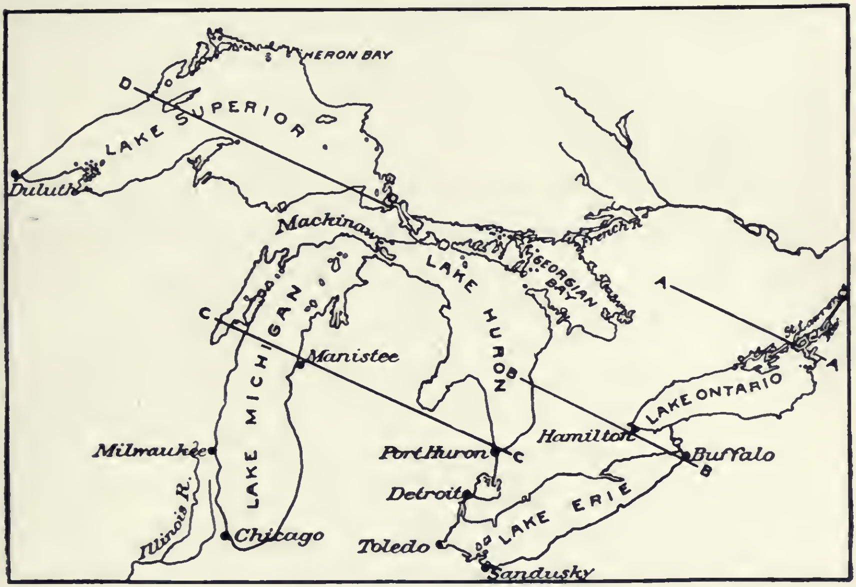


FIG. 100.—Relations of the shores of the Great Lakes to the isobases drawn through their outlets.

The most numerous economic bearings of this geographic change pertain to engineering works, especially for the preservation of harbors and regulation of water levels. But the modifications thus produced are so slow as compared to the growing demands of commerce for depth of water that they may have small importance. It is a matter of greater moment that cities and towns built on lowlands about Lakes Ontario, Erie, Michigan and Superior will sooner or later feel the encroachment of the advancing water, and it is peculiarly unfortunate that Chicago, the largest city on the lakes, stands on a sinking plain that is now but little above the high-water level of Lake Michigan.

PLANS FOR PRECISE MEASUREMENT.

While it is believed that the general fact of earth movement has been established by the present investigation, the measurement of its rate and the determination of its direction fall far short of the precision which is desirable. For the purposes of science the order of magnitude of the change is more important than its precise measurement, but there are involved great economic interests, and these demand more definite information. The account of the present investigation is therefore supplemented by an outline plan of the more elaborate investigation which appears necessary to give measurements of the precision that is desirable.

Existing data are neither full enough nor exact enough to give satisfactory measures of the small quantities sought. Doubtless a more elaborate discussion would yield better results than I have obtained, but the improvement could not be great. Observations by the Lake Survey were conducted for purposes not demanding a high order of precision, and high refinement

was not attempted. The supplementary work done in 1896 attempted only to be good enough for use in combination with the work of 1874 and 1876, and can not serve as the first term of a new comparison. The problem requires a new set of high-grade observations at each station of a carefully planned system, to be followed, after an interval of at least a decade, by a second set of observations at the same stations.

Foreseeing no opportunity to undertake such a work myself, I have formulated in the following paragraphs a plan embodying the results of my experience—a plan intended to afford useful suggestions to some investigator by whom the work may be actually undertaken.

Selection of stations.—To measure the rate of change in any given direction, observations at two stations suffice; but to determine also the direction of change, it is necessary to use three stations grouped in the form of a triangle. The longer the sides of the triangle the better the measurement of rate, and the larger its smallest angle the better the determination of direction. A brief inspection shows that the shores of Lake Michigan and Lake Huron give the best opportunity for the planning of a well-conditioned triangle. Though the narrowness of their connecting strait has led to the giving of separate names, they are really a single lake, and the stretch of their water surface is in every direction greater than that of Lake Superior.

For the purpose in view the point of first importance is the outlet of the lake at Port Huron. This is peculiar in that the plane of the mean water level has here a constant relation to the adjacent land, a relation altogether independent of the progressive deformation of the basin. This station should not be on the St. Clair River, but on the shore of the lake near by.

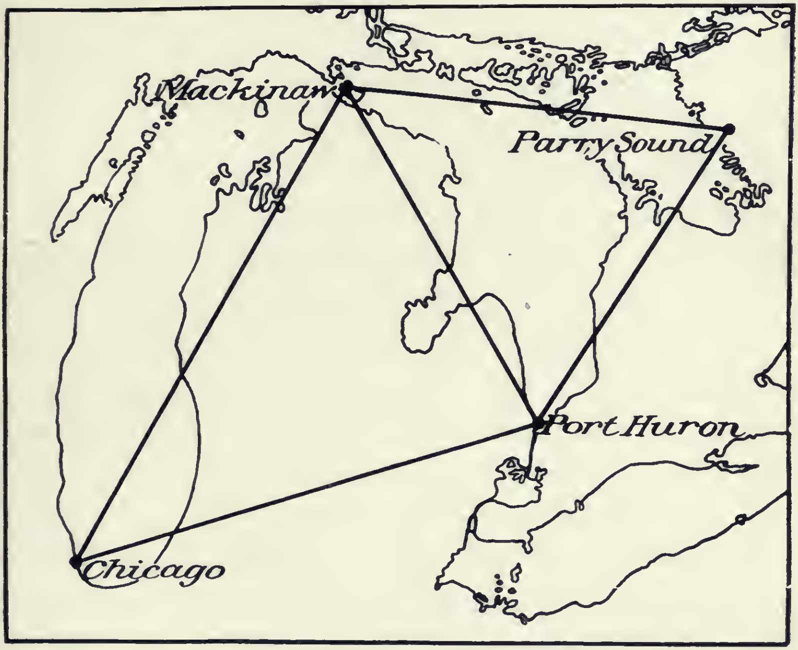


FIG. 101.—Proposed systems of stations for the precise measurement of earth movements.

The second point of vantage is Chicago. As economic interests are more seriously affected by the geographic change at that point than elsewhere, it is desirable to determine directly, by comparison with Port Huron, the rate at which the lake is encroaching on the land.

A third point of prime importance is the Strait of Mackinac. Although the equilibrium levels of the surfaces of the two lakes are the same, there are considerable periods when their equilibrium is disturbed, and during such periods a current flows in one direction or the other through the strait. Only when this current is nil is the whole water body in perfect equilibrium, and it is essential to precise leveling through the water surface either that times of equilibrium be chosen or that due allowance be made for the gradients associated with flow. Observations must therefore be made on the current in the strait, and it is best to connect them with the work of a complete station.

As appears by the annexed diagram (fig. 101), the triangle formed by these three stations is well conditioned as to size and form; the lengths of its sides are approximately 225, 275 and 310 miles, and its smallest angle is about 45 degrees.

While the proper use of these three stations will give answer to the questions of greatest economic and scientific importance there will be material scientific advantage in adding a fourth station to the system. It should be placed somewhere on the north shore of Georgian Bay, and, giving consideration to accessibility as well as geographic position, it is probable that Parry Sound should be selected. By adding this station another well-conditioned triangle would be completed, and there would result an additional determination of the rate and direction of tilting. If rate and direction vary from place to place the fact will probably be brought out. There would be additional

advantage in the fact that Parry Sound and Chicago are separated by the greatest practicable distance in the direction of maximum change, so that a comparatively short period of time might afford a valuable measurement. The approximate results of the present investigation indicate that the change in the relative height of Parry Sound and Chicago in ten years would be about 2 inches.

Conditions controlling equipment.—In order to plan intelligently the system of observations, full consideration should be given to the conditions affecting the problem, and provision should be made for all possible sources of error. Prominent among these are the various factors which modify the water level at points on the lake shore. Such factors have been considered in the preceding discussion of gage data, but they are assembled here in a more systematic way.

The lake continually receives water from streams and from rain, and continually parts with water by discharge at its outlet and by evaporation. In the long run gain and loss are equal, but for short periods they are usually unequal; so that from day to day from season to season, and from year to year the volume of the lake and the consequent mean level of its surface are continually changing.

In bays and estuaries there are local temporary variations occasioned by the floods of tributary streams.

There are solar and lunar tides, small as compared to those of the ocean, but not so small that they may be neglected.

The wind pushes the lake water before it, piling it up on lee shores and lowering the level on weather shores. During great storms these changes have a magnitude of several feet, and the effect of light wind is distinctly appreciable. Even the land and sea breezes, set up near the shore by contrasts of surface temperature, have been found to produce measurable effects on the water level.

There is also an influence from atmospheric pressure. When the air is in equilibrium, if that ever occurs, the pressure is the same on all parts of the lake surface, and the equilibrium of the lake is not disturbed; but when the air pressure varies from point to point this variation of pressure is a factor in the equilibrium of the water surface, the surface being comparatively depressed where the air pressure is greater and elevated where it is less.

When a storm wind ceases, the water not merely flows back to its normal position but is carried by momentum beyond, and an oscillation is thus set up which continues for an indefinite period. A similar oscillation is started whenever the equilibrium is disturbed by differences of atmospheric pressure; and these swaying motions, called seiches, analogous to the swaying of water in a tub or hand basin, persist for long periods. In fact, they bridge over the intervals from impulse to impulse, so that the water of the Great Lakes never comes to rest.

Every disturbance which causes the water to rise on one shore of the lake and fall on the other interferes with the equilibrium between the two lakes at the Mackinac Strait. If a strong wind blows the water eastward, raising the level on the east shores of the lakes and lowering it on the west shores, there is high water at the west end of the strait and low water at the east, producing a current toward the east; and when the wind ceases the water that has poured from Lake Michigan to Lake Huron must return, producing a current in the opposite direction. Theoretically, analogous effects should be produced by tides and barometric gradients, and there can be little question of their detection if the phenomena at the strait are studied.

These various influences work independently but simultaneously, and their effects are blended in the actual oscillations of the water surface at any point. In using the water surface for the purpose

of precise leveling, it is necessary to take account of all such factors and make provision for the avoidance or correction of the errors they tend to produce.

Equipment.—In view of the complexity of the phenomena to be analyzed, it is desirable that most of the instruments employed be of the automatic kind, giving continuous record. While such instruments accomplish much more than could be done by an observer alone, they do not dispense with his services. They are complex as compared to the apparatus for personal observation, and can be successfully employed only by a man of scientific training. The first essential, therefore, at each of the stations is an expert observer.

The gage employed for the determination of water height should be of some automatic type, giving a continuous record. This is necessary in order that the study of the record may furnish data for the complete elimination of errors from tides, seiches, and land and sea breezes. The gage should be protected, not only from the direct shock of waves, but from all secondary agitation of the water due to wave shock. It should be so installed as to be secure from settling. The height of its zero should be readily verifiable.

Near each station there should be at least three benches, constructed with special reference to permanence and stability. They should be independent of one another and independent of other structures.

Pressure of the air should be continuously recorded by a barograph, carefully standardized. A wind vane and anemometer should give automatic records.

At Mackinac there should also be means for securing a record of the direction and velocity of water currents.

Treatment of observations.—Stress having already been laid on the importance of putting the work in expert hands, it would be

unwise to attempt the formulation of a code of instructions for either the making or the reduction of observations; but there may be advantage in a few suggestions based on experience acquired in the present investigation.

While it is doubtless possible to deduce from a study of currents in Mackinac Strait a theory of the relation of those currents to the equilibrium conditions of the two lakes, it will probably be found best to use the current observations chiefly for the discrimination of favorable and unfavorable times, and to compare the lake-level observations only for times when the current at Mackinac is gentle. It will also be better to avoid the use of observations during the prevalence of strong winds or high barometric gradients than to attempt the application of corrections for those factors.

The times not barred by high winds, high gradients and currents will ordinarily not be found to have such duration and distribution that tidal effects can be eliminated by including complete tidal cycles. It will therefore be necessary to discuss the solar and lunar tides for each station and prepare tables of correction to be applied to all observations employed. The same treatment will be necessary for the effects of land and sea breezes. Barometric gradient of amount too great to be ignored nearly always exists, and this, as determined by observations at the stations themselves, should be the subject of computation and correction.

Seiches should be fully discussed for each station, and the observations finally used should be grouped in periods of sufficient length to eliminate the seiche effect.

SUPPLEMENT.—INVESTIGATION BY MR. MOSELEY.

The main body of manuscript for this paper was prepared in June and July, 1897. An abstract was communicated in August to the American Association for the Advancement of Science,

meeting in Detroit, and a fuller abstract was printed in the September number of the National Geographic Magazine.* As a result of this publication I became acquainted with a cognate investigation by E. L. Moseley, of Sandusky, Ohio. His data and results were communicated to the Ohio Academy of Sciences in December, 1897, and printed soon afterwards in a Sandusky newspaper. They received more permanent as well as fuller presentation in an article contributed to the Lakeside Magazine,† and this article reaches me while the proof sheets of the present paper are in hand. As will be readily understood from the following abstract, the data he has gathered constitute an important contribution to the subject.

North of Sandusky Bay, near the west end of Lake Erie, is a cluster of islands, of which the five largest are each several miles in extent.‡ About them the water is shallow, and if the lake were lowered 30 to 35 feet they would all be connected with the mainland. On these islands grow many species of wild plants, and the origin of this flora is related to the geologic history of the islands. There was a time during the ice retreat when the whole basin was covered by a glacial lake. If the water was gradually lowered from the plane of the glacial lake to the present plane of Lake Erie, the islands were at first barren and were eventually occupied only by such plants as were in some way conveyed across the intervening straits, from 2½ to 3 miles wide. As Moseley points out, there are many modes of such adventitious introduction, but they could not be expected to give to the islands a flora so varied as that of the adjacent mainland.

If, on the other hand, as inferred from the slopes of the old shore lines and other data, the attitude of the land was different when the

* Modification of the Great Lakes by earth movement: Nat. Geog. Mag., September, 1897, Vol. VIII, pp. 233-247.

† Lake Erie enlarging; the islands separated from the mainland in recent times; by E. L. Moseley: The Lakeside Magazine, Lakeside, Ohio, April, 1898, Vol I, pp. 14-17.

‡ For the relation of these islands to the lake and the isobase of its outlet, see fig. 100, p. 640.

glacial lake was drained away, the original Lake Erie occupied only the eastern part of the Erie basin, and the western part, including the district of the islands, was dry land. Subsequently, from the tilting of the land, the lake waters advanced westward so as to flood the straits and convert the lowland hills into the present islands. In connection with such a geologic history the islands would have acquired their flora at the same time with the mainland, and should now present the same variety of species, so far as local conditions permit. Moseley has carefully compared the insular flora with that of the mainland, and finds that the only mainland species which do not occur on the islands are such as do not find there a congenial soil. The botanic evidence thus supports the geologic, and verifies the conclusion that the land has been tilted toward the southwest since the birth of Lake Erie.

The islands are composed largely of limestone and are surrounded by limestone cliffs. In South Bass or Put-in-Bay Island there are caves opening at the water's edge and partly occupied by lake water. Exploring these, Moseley finds stalactites extending from the roof down into the water, and stalagmites lying 3 or 4 feet below the present surface of the lake. Comparing the present water level with the lowest levels known in recent times, it appears that these stalagmites have not been above water during the present century, and as stalagmites are formed only in the air, it is clear that the lake has encroached on the land since they were made.

These data show only that a change has occurred, and ascribe no date, but other phenomena observed in the neighborhood of Sandusky indicate clearly that change is now in progress. A tract of land on which hay was made in 1828 is now permanently under water. A tract of land one-half mile square, surveyed in 1809, has since become marsh, with water and mud 12 to 18 inches deep. Various parts of Sandusky Bay where rushes grew within the

memory of men still living are now covered with open water. "By the high water that prevailed in 1858 to 1860 large trees were killed in many places where the waves could not reach them." "Hundreds of walnut stumps are still standing on the border of the marshes east of Sandusky where even now, although the water is lower than usual, it is too wet for walnut trees to grow. One that stood recently on ground only 6 inches above the present lake level measured 5 feet 4 inches in diameter. We may infer from this that during the life of this tree, probably over 300 years, the water was not so high as in the present century." Many stumps and prostrate trunks with roots and branches attached are found from 1 to 4 feet below the present lake level, and in one locality it is inferred that the lake during the life of the trees must have been as much as 8 feet lower than "during much of the time for the last forty years."

These various facts, and others of the same tenor enumerated by Moseley, are in complete accord with the qualitative results derived from the discussion of gage readings, but, like the data gathered by Stuntz, they suggest a more rapid rate of change than do those results.

AN ACCOUNT OF THE RESEARCHES RELATING TO THE GREAT LAKES.

By Dr. J. W. Spencer, Toronto.

PREFACE.

The following "Account of the Researches Concerning the Great Lakes" was read before the Detroit meeting of the American Association for the Advancement of Science in August, 1897.* Although two summers have been spent in field work in the mountains of New York, New England and Canada, only one or two notes † have appeared, so that the only important contribution by the author on this questien since the writing of the Detroit paper is that on "Another Episode in the History of Niagara," ‡ which is a sequel to the former paper on "The Duration of Niagara Falls." An abstract of this recent paper will be appended.

Twenty years ago very little was known of the history of the Great Lakes and of Niagara Falls. Since then the origin of the lake basins has been explained by the discovery of the buried and drowned ancient Laurentian River and its tributaries, the valleys of which have been obstructed by drift, their altitude above the sea now greatly reduced, and their respective barriers in part raised up by the recent unequal tilting of the earth's crust. These physical changes have also diverted the drainage of western Pennsylvania, so that now the upper Ohio and Allegheny Rivers discharge into the Mississippi in place of into the St. Lawreuce, through the Erie Basin, as they formerly did.

The after-history of the lakes has been partly studied, for their old and now deserted shore lines have been approximately mapped over a large area, and the amount of subsequent tilting of these old water lines has been measured. The most interesting feature in their subsequent history is the change of outlets, both past and in prospect. Thus the three uppermost lakes discharged through Lake

* American Geologist, Vol. XXI, pp. 110-123, 1898.

† Ib., Vol. XXII, p. 262, 1898.

‡ Am. Jour. Sc., series IV, Vol VI, pp, 639-450, 1899.

Huron towards the east, so that the Niagara did not receive any more than the waters of the Erie Basin until in a recent period. This discovery was first made by the writer in 1888,* although more recently Mr. F. B. Taylor, by a remarkable method of reasoning, has gone out of his way to ascribe it to another,† although this other has not so claimed it, so far as is known to the writer. So also the rate of rise of the earth's crust throughout the lake region, and the consequent hypothesis announced at the same time that the Falls of Niagara would probably cease to exist in the near geological future, owing to the diversion of the waters of the four upper Great Lakes to the Mississippi by way of Chicago, was first announced by the writer in 1894.‡ This has been confirmed by the subsequent researches of Prof. G. K. Gilbert,§ with almost identical results when reduced to the same standard. In his paper (p. 602) Prof. Gilbert says: "So far as I am aware this paper broaches for the first time the idea of the differential elevation of the lake region, and it contains the only observations that have been cited as showing the recent changes of that character. In late years the subject has been approached from the geologic side, and Dr. J. W. Spencer has expressed his opinion that the warping or tilting of the whole region is now in progress." From the standpoint of measuring the changes of level of the lake waters, I believe that Prof. Gilbert is correct in his claim, but they only confirm the correctness of the previous geological determinations. The tilting of the beaches has been measured by several of us, but the direction of the tilting was determinable only after my surveys on the Canadian side of the lake enabled us to triangulate the direction of the rise, and in my papers between 1888 and 1891 this deter-

* Proc. Am. As. Ad. Sc., Vol. XXVII, pp. 198–200, 1888.

† Bull. Geol. Soc. Am., Vol. IX, p. 180, 1898. See also Am. Jour. Sc., series IV, Vol. VI, p. 439 (foot-note).

‡ Am. Jour. Sc., Vol. XLVIII, pp. 455–472, 1894.

§ Eighteenth Annual Report U. S. Geological Survey, p. 639, 1898.

mination of the direction of the rise was calculated and shown only to be confirmed by all subsequent measurements, including the recent paper of Prof. Gilbert. But the difficulty awaiting us was that we did not know the rate of warping, for, if found for one district, it could be calculated for the whole lake region. Of course it was not an absolute rate of rise, but the differential rise of the lake region. However, I found that during the last 1500 years the mean rise in the Niagara district was from 1¼ to 1½ feet per century, as compared with Chicago. To make it a measurement of the absolute rise would be to add or subtract the changes of the earth's crust at Chicago, which are not known. But the rate of rise north of the Adirondack district was three times as great, and so on for other regions. With this mean rate of rise discovered as in progress for the last 1500 years, it becomes no bold prediction to apply it to the diversion of the Niagara drainage to the Mississippi and the consequent extinction of the Falls. This hypothesis was first announced in March, 1894,* or three and a half years before it was confirmed by Mr. Gilbert's estimates of the fluctuations of the lakes. The results of the latter methods almost exactly confirm the earlier geological discoveries of a rise of the earth's crust, and the consequent confirmation of the hypothesis of the extinction of Niagara, at about the same date, when the calculations are reduced to the same basis.

The history of the Falls is so intimately connected with that of the lakes, and in their archives we find that there have been several changes in the height of the Falls as well as great variations in the amount of water that passed over them during the different episodes. All of these studies are gradually leading us to more and more nearly approach the correct determination of the age of the Falls.

* Am. Jour. Sc., Vol. XLVIII, pp. 455-472, 1894.

[*From The American Geologists, Vol. XXI, February*, 1898.]

AN ACCOUNT OF THE RESEARCHES RELATING TO THE GREAT LAKES*.

By Dr. J. W. Spencer.

An old text-book upon geology briefly says that the lake basins are due to movements of the earth's crust. What the movements were and how they affected the history of the great lakes was left a subject of discovery for recent years. In the meanwhile, theories arose as to their origin, the disposal or modification of which was fraught with difficulties as great as those of discovering the history itself. Ramsay had attributed the origin of the American lakes to glacial excavation;† Hunt, Newberry, Carll and many others had collected the evidence of buried channels occurring in the lake region. Gen. G. K. Warren‡ had followed up the observations of Prof. H. Y. Hind § in the history of the Winnepeg basin, and proposed the northeast warping as closing the Ontario basin, to such a degree that he may be considered the father of lacustrine geology. But the great impetus towards the investigation of the great lakes is due to Prof. J. S. Newberry, ‖ whose contribution was followed by one from Prof. E. W. Claypole.¶ To give a full account of the researches concerning the great lakes, and to tell how each author had contributed to the subject would make a very long chapter. As the present writer has been so closely connected with the pioneering study of the subject, and has announced progress

* Read at the Detroit meeting of the A. A. A. S., 1897.

† Quart. Jour. Geol. Soc., Lond. vol. XVIII, pp. 185-204, 1862.

‡ Appendix J., Rep. of the Chief of Engineers, U. S. A., 1875; Am. Jour. Sci. (3), vol. XVI, 1878, pp. 416-431.

§ Report on the Assiniboine and Saskatchewan Exploring Expedition. By Henry Youle Hind. Toronto, 1859, pp. 1-20.

‖ Geology of Ohio, vol. II, 1897, pp. 72-80.

¶ On the pre-Glacial Geography of the region of the Great Lakes, E. W. Claypole. Can. Nat., vol. VIII, 1877, pp. 187-206.

from time to time before the American Association, it seems a fitting opportunity to tell how his investigations have been influenced by his co-workers, leaving to others the narration of the most recent studies.

Newberry followed up on the lines of Ramsay in attributing the basins of the lakes to glacial excavations, yet there was a counter current in his writings which finally advocated that the glacial excavation had taken place only after their courses had been predetermined by river action. Adopting the teachings of Agassiz and Newberry, and going much farther, an influential school was developed which attributed the superficial features of the northern regions almost entirely to the action of continental ice—in spite of the teachings of Lesley, Dawson, Whitney and others. The extreme views, as represented by Dr. G. J. Hinde,* made the ice plough dig out the St. David's, Dundas and other valleys, irrespective of their direction, as compared with that of the ice flow. Such speculations were most common at the close of the eighth decade of the century, when the writer commenced his studies upon lacustrine history—concerning which his first paper was on the "Discovery of the Outlet of the Basin of Lake Erie," etc.† (1881). The appearance of this "avant courier" was due to the enthusiastic reception given by Prof. J. P. Lesley to the writer's discovery of the reduction of rocky barriers beneath the superficial drift between Lake Erie and the Dundas Valley, at the head of Lake Ontario, indicating an outlet for the Erie basin by a channel, the lower end of which is deeply buried by drift deposits. Prof. Lesley pointed out that this discovery satisfied the necessity

* Glacial and interglacial strata of Scarboro Heights, etc. Canadian Journal, April, 1877, p. 24.

† Discovery of the Preglacial Outlet of the Basin of Lake Erie into that of Lake Ontario; with notes on the Origin of our Lower Great Lakes. By J. W. Spencer; Proc. Amer. Phil. Soc., XIX, 198, 2n., March 30, 1881, pp. 300–337.

for some such outlet to the Erie Basin, as Hunt and Newberry had found buried channels beneath the lake, and Mr. J. F. Carll had discovered that the drainage of the Upper Allegheny and other streams had been reversed, having flowed northward into the Erie Basin in preglacial days.

The writer's paper referred to not only described the outlet of the Erie Basin, but also showed that the Niagara River was not needed in ancient times. Shortly afterwards this idea was confirmed by Dr. Julius Pohlman* who found that the Niagara channel was not sufficiently deep for the drainage of the buried valleys in the vicinity of Buffalo.

In the same paper the valley-like features beneath the lake waters were analyzed and established. But at that time the course of the ancient drainage could not be traced beyond the meridian of Oswego. The writer also objected to the theory of the glacial excavation of the basins on account of the stream-like sculpturing of the land and the sub-lacustrine escarpments; and on account of the glaciation of the region being everywhere at sharp angles to the escarpments, whether above or below the surface of the lakes. These views and the discovery of the outlet for the ancient Erie Basin confirmed the teachings of Prof. J. P. Lesley, who, from being a progenitor of the science of topography, became the father of geomorphy, of which the lake history is one of the phases. In speaking of the origin of the lake valleys, Prof. Lesley† says: "For a number of years I have been urging upon geologists, especially those addicted to the glacial hypothesis of erosion, the strict analogy existing between the submerged valleys of Lakes Michigan, Huron and Erie and the whole series of dry Appalachian 'valleys of VIII,' stretching from the Hudson River to Alabama; also of Green Bay, Lake Ontario and

* The Life-history of Niagara. By Julius Pohlman. Trans. Am. Inst. Min. Eng.

† Report Q4 of the Geological Survey of Pennsylvania, 1881, pp. 399-406.

Lake Champlain, with all the 'valleys of II and III.' One single law of topography governs the erosion of them all, without exception, whether at present traversed by small streams or great rivers, or occupied by sheets of water, the only agency or method of erosion common to them all being that of rainwater, not in the form of a great river, because many of them neither are nor ever have been great waterways."

Notwithstanding the shortcomings and what are now known to be errors of detail, the paper on the preglacial outlet of Erie attracted considerable attention as a new departure, and at the time Prof. James Geikie, who is well known to be one of the leading glacialists, expressed himself as follows, under date June 21, 1881: "I have always had misgivings as to glacial erosion of the Great Lakes, * * * and now your most interesting paper comes to throw additional doubt upon the theory in question. Possibly those who have upheld that view will now give in. Your facts seem, to me at least, very convincing. I never could understand how those great lakes of yours could have been ground out by ice. The physical conditions of the ground seem to me very unfavorable." Prof. G. K. Gilbert, on June 15, 1881, wrote: "My first geological field work was in the drift of the Erie basin, and the problem of the origin of the basins of the great lakes has always had great attraction for me. Had I been able to understand its solution, my working hypothesis would have been that which you have demonstrated so thoroughly. * * * The matter has certainly never received a demonstration until your paper appeared. * * *"

At this time the writer was struggling to find the outlet of the basins, and looked in every possible direction for buried channels without avail. While the St. Lawrence valley, beyond the outlet of lake Ontario, was evidently only a continuation of the drowned

valley occupied by the lake, and while the lower St. Lawrence indicated an elevation of the continental region to more than 1,200 feet (when the cañon of the Saguenay was being excavated), the evidence of the local oscillation of the earth's crust was not yet forthcoming. The deep cañon of the Dundas valley, and the observations of Prof. Gilbert that the Irondequoit bay was drowned to a depth of 70 feet, was taken as evidence of terrestrial oscillation, but later the writer found that the St. Lawrence, after leaving Ontario, was in part flowing over a valley buried or drowned to a depth of 240 feet; accordingly the Dundas and Irondequoit valleys were no evidence of local oscillation, which had to be found elsewhere.

In concluding a notice of this early work,* the modern aspect of the Niagara River was emphasized, and the valley of St. Davids was regarded as of inter-glacial origin—in deference to the prevailing theories of the time—in place of being, as is now known, the channel of an insignificant stream of greater antiquity. The Finger lakes of New York were explained as closed up valleys which had formerly drained the rivers of the highlands of New York, as for example Seneca lake, which has since been found to be the ancient course of Chemung and its tributaries. About this time the writer, from the data collected by the Geological Survey of Pennsylvania, pointed out the probability that the Monongahela and upper Ohio had formerly been reversed and drained into the Erie valley.* This hypothesis was afterward amplified by Dr. P. Max Foshay,† disputed by Prof. I. C. White; modified and confirmed by Mr. F.

*A short study of the Features of the Great Lakes, etc. J. W. Spencer. Proc. A. A. A. S., vol. XXX, 1881, pp. 131-146; and Surface Geology of the Region about the western end of Lake Ontario. J. W. Spencer, Can. Nat., vol, X, 1882, pp. 213-236, and 265-312.

*On the ancient upper course of the Ohio river emptying into lake Erie. Proc. Am. Phil. Soc., Phil. vol. XIX, 1881.

†Preglacial Drainage and recent Geological History of western Pennsylvania. Am. Jour. Sci., vol. XL, 1890, pp 397-403.

Leverett,* and finally, with some modifications, reconfirmed by Prof. I. C. White.† In order to test the validity of his objections to the hypothesis of glacial excavation, the writer visited Switzerland and Norway for the purpose of personally observing the mechanical effects of modern glaciers, with the result that he saw in them only the agents of abrasion—the ice moulding itself round obstructions, or smoothing off irregularities, and not ploughing out channels.‡ Indeed, in a more recent visit to Norway, it became apparent that the great glacial valleys still preserve many base levels of erosion—the doctrine of which has not been applied to them, and consequently their history is as yet unwritten. The extreme views concerning glacial erosion, held a decade ago, are now greatly modified and do not belong to the present day.

In 1882, fragments of great beaches, and others which were delta deposits, were described as occuring about the western end of Lake Ontario at various elevations from 500 feet above the lake down to its present level.§ Other fragments of beaches had been known for many decades, the most notable of which were the ridge roads of New York state, that Prof. James Hall, as early as 1842, found to be rising gently upon proceeding eastward ;‖ and the same was found to be true at the eastern end of Lake Ontario. About this time Prof. Gilbert was studying the beaches of the western lakes, and Mr. Warren Upham those of the Winnipeg basin. The beaches in both places were found to record the evidences of gentle terrestrial movements. Following up his investigations, Prof. Gilbert connected the various fragments of a great beach upon the

*Pleistocene fluvial plains of western Pennsylvania. Am. Jour. Sci., vol. XLII, 1891, pp. 200–212; and Further studies of the Upper Ohio basin. Am. Jour. Sci., vol. XLVII, 1894, pp. 247–283.

†American Geologist, vol. XVIII, 1896, pp. 368–379.

‡The erosive power of glaciers as seen in Norway. Geol. Mag. Lond., Dec. iii, vol. IV, 1887, pp. 167–173.

§ Surface Geology about the region of the western end of Lake Ontario, cited before.

‖ Geology of New York. Vol. IV, 1843, p. 351.

southern and eastern sides of Lake Ontario, as far as Adams Centre, near Watertown, N. Y.,* and found that the old waterline was deformed to the extent of several hundred feet in proceeding northeastward. This was an admirable piece of work, which was invaluable to the writer, who extended the observations further† and made use of them in measuring the amount of the long sought for terrestrial deformation as the outlet of Lake Ontario, and found that these post-glacial movements were sufficient to account for the rocky barrier across the Laurentian valley, producing the basin which retains the waters of Lake Ontario. The channels across this rocky barrier, however, were closed with drift deposits reaching to a depth of 240 feet. In thus establishing the ancient drainage of the Ontario basin, after years of observation, often representing but little progress, the phenomena of the basin were discovered without the glacial theory of erosion. Then the writer found that the drowned channels across Lake Huron, and passing through Georgian bay, continued beneath hundreds of feet of drift, eastward of the Niagara escarpment, and joined the Ontario valley a few miles east of Toronto. A similar channel (the Huronian) crossed the State of Michigan, passed through Saginaw bay, and over the sub-lacustrine escarpment, to the deeper channel of the Huron basin.‡ The Erie (Erigan river) drainage had been found to pass into the head of the Ontario basin. Thus was discovered the course of the ancient Laurentian river and its tributaries of antiquity. These upper basins were also affected by the terrestrial tilting recorded in the beaches, as well as by the drift obstructing them.

Prof. Gilbert, who had, many years before, mapped beaches at the head of lake Erie§ afterwards measured the deformation recorded

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* Report of the meeting of the Am. Assc. Adv. Sci., Science, Sept., 1885, p. 222.

† The Iroquois Beach: a Chapter in the Geological History of Lake Ontario, by J. W. Spencer. Trans. Roy. Soc. Can., 1889, pp. 121-134. (First read before Phil. Soc., Wash., March, 1888.)

‡ Origin of the Basins of the Great Lakes. Q. J. G. S. (Lon.), vol. XLVI, 1890, pp. 523-533.

§ See Geology of Ohio, vol. II, 1874.

in the deserted shore at the eastern end of the lake;* while the writer surveyed the old water margins across Michigan, and on the Canadian sides of Lakes Ontario, Erie and Huron, and in portions of New York.† After this, very little work was done upon the deserted shores for several years, when Mr. F. B. Taylor commenced his researches about the northeast portion of Georgian bay, Lake Michigan, etc.,‡ and Dr. A. C. Lawson carried on similar observations north of Lake Superior,§ and Prof. H. L. Fairchild in New York. The deserted beaches show but little terrestrial oscillation about the western end of lake Erie, but it increases towards the northeast and amounts from four to seven feet per mile.

With the surveys of the deserted beaches, new questions arose concerning the history of the lakes and of Niagara River, which forms an inseparable chapter. At the same time, opposing hypotheses presented themselves.

None of the beaches have been fully surveyed. They occur at various altitudes from near the greatest elevation of the land down to the levels of the lakes, and they have not always been separated from other Pleistocene deposits. While there are questions as to the higher forms, those from lower levels have undoubtedly been accumulated about extensive bodies of water—the character of which is the subject of disagreement. The writer has regarded them as accumulations at sea-level, and other observers as margins of glacial lakes, irrespective of their elevation. The theoretical aspect is not one likely to be settled speedily. Those who advocate the

* The History of the Niagara River. 6th Rept. Com. State Res. Niag., Albany, 1890, pp. 61-84.

† The Iroquois Beach, etc., cited before. Deformation of the Iroquois Beach and Birth of Lake Ontario, Am. Jour. Sci., vol. XL, 1890, pp. 443-451; Deformation of the Algonquin Beach and Birth of Lake Huron, Ib., vol. XLI, 1891, pp. 11-21; High Level Shores in the Region of the Great Lakes, and their Deformation, Ib., vol. XLI, 1891, pp. 201-211; Deformation of Lundy Beach and Birth of Lake Erie, Ib., vol. XLVIII, 1894, pp. 207-212.

‡ Numerous papers recently published in Am. Jour. Sci., American Geologist, and Bul. Geol. Soc. Am.

§ Sketch of the Coastal Topography of the North Side of Lake Superior. 20th Report of the Geol. Sur. Minnesota, for 1891, pp. 181-289.

glacial character of the lakes have sought to terminate the beaches against morainic deposits to the northeast, but their ice dams have been frequently thrown along lines beyond which the beaches have subsequently been traced. Thus Prof. Claypole* made ice dams in Ontario where open water, bounded by beaches, was afterwards found to prevail. At Adams Centre, Prof. Gilbert drew an ice dam for the Ontario basin, beyond which, however, the writer found that the old shore line extended, and this was later confirmed by Prof. Gilbert. Mr. Leverett made an ice dam at Cleveland, beyond which the writer has been informed by two observers that the beach extends, and Prof. Gilbert and Mr. Leverett described another glacial dam near Crittenden, N. Y., beyond which the beaches have been discovered by Prof. Fairchild. Another diagnosis of the glacial lake is the occurrence of gravel floors over low divides, which are regarded as the outlets of them, and upon this feature alone many such lakes have been named. But the advocates of these glacial outlets have not explained how the terraces (at hundreds of feet above the drainage) upon the southern side of them are indistinguishable in character from those upon the northern side.† If these supposed outlets be evidence *per se* of glacial dáms then the most perfect which the writer has ever seen may be found within 16° of the equator, at an altitude of less than 800 feet, suggesting that the Mexican gulf had a glacial dam, discharging into the Pacific ocean across the Isthmus of Tehuantepec — a suggestion which no one would seriously consider. The writer has also presented the hydrostatic objections‡ to the impossible long continuance of some of the supposed dams, the location of which demands their drainage across ice itself, which

*Report of the meeting Am. Assoc. Adv. Sci. Science, Sept., 1895, p. 222.

†Channels over divides not evidence *per se* of glacial dams. J. W. Spencer. Bull. Geol. Soc. Am., vol. III, 1891, p. 491.

‡Post-Pliocene continental subsidence versus ice-dams, by J. W. Spencer. Bull. Geol. Soc. Am., vol. II, pp. 465–476, 1890.

would soon be penetrated by the warmer waters so as to reduce their level. By straightening out the deformation recorded in the deserted shore-lines, some of the beaches are shown to have undoubtedly been formed at sea level.* While recent surveys report the discovery of additional glacial lakes, or the splitting up of those first described under new names, the survey of the high level terraces in the mountain regions has suggested to the writer counterbalancing evidence of the occurrence of glacial dams, but this is a study which has been postponed, partly on account of the prejudice against post-glacial subsidence and partly on account of the writer's absorption in other questions of physical changes. Whatever may be the ultimate fate of the theory of glacial dams, the opposing hypotheses have given zest to the investigations to the degree of advancing our knowledge of the lake history.

In the survey of the beaches, besides the terrestrial deformation recorded, there seems to be no more important discovery than when the writer found how the Huron, Michigan and Superior waters (the Algonquin gulf or lake) originally emptied to the northeastward of the Huron basin in place of discharging into Lake Erie; after which, by the northeastern tilting of the land, "the waters were backed southward and overflowed into the Erie basin, thus making the Erie outlet of the upper lakes to be of recent date."† This conclusion was established by the survey of the Algonquin beach which recorded the necessary tilting. The first survey was suspended near Balsam lake, where an overflow was found; and, accordingly, in the original announcement, the generalizations were not carried farther; although there was a lower depression in the vicinity of Lake Nipissing, which was shortly afterwards made use

*The Iroquois Beach, etc., cited before; and, Deformation of the Iroquois Beach, cited elsewhere.

†Proc. A. A. A. S., vol. XXXVII, 1888, p. 199.

of by Prof. Gilbert* and the writer. With the further elevation of the land, the lower beaches — partly measured at that time (1887–8)—represented the surface of the Algonquin water discharging by the Nipissing route alone.† This has since been worked out by Mr. Taylor.‡

Co-existing with the Algonquin gulf or lake was the Lundy gulf or lake, occupying part of the Erie basin, and extending into the Ontario, having substantially the same level. Both of these bodies of water extended much farther towards the northeast than their successors, although more contracted in the opposite directions — the effect of the more recent tilting of the land. Prior to the existence of these separate bodies of water, higher shore-lines were formed, and the great gulf or lake bounded by them was called the Warren water, which name the writer has defined as applicable to the great open water of the region, until after the formation of the Forest Beach — its most perfect episode — after which it was dismembered into the Algonquin and Lundy waters.§

During the changing stages of Warren water, its configuration was somewhat varied but not sufficiently to call the water by a multiplicity of names, according to the changing levels. The old shore lines form prominent features, requiring nomenclature for the most important. And additional naming only adds confusion. Some of the beaches have been renamed by Mr. Leverett,‖ contrary to the usage of naturalists.

With the continued elevation of the land, the Algonquin water sunk to the level of the Nipissing beach (of Taylor) and the Lundy became dismembered, and formed an insignificant Lake Erie.¶ In

*The history of the Nipissing River.

†Deformation of the Algonquin Beach, cited before.

‡The Ancient Strait of Nipissing. F. B. Taylor. Bull. Geol. Soc. Am., vol. V, 1893.

§ High-level shores in the region of the Great Lakes, etc., cited before.

‖ On the correlation of the New York moraines with the raised beaches of lake Erie, by Frank Leverett. Am. Jour. Sci., vol. L, 1895, pp. 1–20.

¶Proc. A. A. A. S., 1888, p. 199.

the Ontaria basin, the water sunk to the Iroquois beach and lower levels, and Niagara Falls had their birth, after the river had first been a strait. Remnants of beaches of that time were long ago observed, not only in the vicinity of Niagara, but also at the head of the lake. With the temporary pauses recorded, the waters of the upper level were speedily lowered to that of the Iroquois beach, and then the Niagara river descended only 200 feet, in place of 326 feet, as at present. The effect of this diminished descent upon the excavating power of the falls was first pointed out by the writer in 1888* and published in 1889. With the continued lowering of the waters in Ontario basin, the descent of the Niagara increased to 80 feet more than at present, as first shown by Prof. Gilbert; but later, by the tilting of the earth's crust north of the Adirondack mountains, the outlet of the Ontario basin was raised, causing the backing of the waters, so as to reduce the descent of Niagara river to its present amount.

In 1886, after the third survey of Niagara Falls (by Prof. Woodward), the rate of recession was found to be much greater than had formerly been supposed. Prof. Gilbert then made a short study of the falls, the conclusions concerning which are summed up as follows by that author: † "The problem admits of expression in an equation:

Age of gorge equals $\dfrac{\text{Length of gorge.}}{\text{Rate of recession of falls.}}$
—Effect of antecedent drainage.
—Effect of thinner limestone.
—Effect of thicker shales.
—Effect of higher fall.
—Effect of more floating ice.
±Effect of variation of detrital load.
±Effect of chemical changes.
±Effect of changes of river volume.

* The Iroquois Beach, etc. Trans. Roy. Soc. Can., 1889, p. 132.

† The Place of Niagara Falls in Geological History. G. K. Gilbert. Proc. Am. Adv. Sci., vol. XXXV, 1886, pp. 222-223.

"The catchment basin was formerly extended by including part of the area of the ice sheet; it may have been abridged by the partial diversion of Laurentian drainage to other courses." He had divided the length of the gorge by the maximum rate of recession, finding the product to be 7,000 years. If the equation be carefully examined, together with the cited quotation, all the important changing effects in the physics of the river would lessen the estimated age of the cataract below 7,000 years, except the effect "by partial diversion of the Laurentian drainage to other courses," of which no evidence was suggested; nor was any lengthening of time shown as necessary, by the long interior hight of the falls, Henceforth, Prof. Gilbert was naturally quoted as an authority that the age of the falls was only 7,000 years. This conclusion did not satisfy the writer, who from the evidence of the beaches, especially the Iroquois,* found that the rate of recession must have been for long ages much less than now, on account of the interior height of the falls; and also on account of the greatly diminished volume of water, owing to the overflow of the upper lakes to the northeast, until in recent days. But how much of the work of the falls had been done before the upper lakes were turned into the Niagara drainage, for a long time seemed undeterminable, until the features of Foster's flats were used for measuring the amount of work performed in that early episode. This standard has since been confirmed by other phenomena not yet published; and from a different standpoint the distance of the early recession has been agreed to by Prof. Gilbert, who now considers the age of the falls far greater than that formelry suggested by his paper in 1886. From all the available data up to 1894, the writer computed the age of Niagara Falls at 32,000 years.† Of the various episodes, that of the cataract passing the narrows of the whirlpool rapids still

*See Trans. Roy. Soc. Can., 1889, p. 132; and Proc. A. A. A. S., 1888, p. 199.

†Duration of Niagara Falls. Am. Jour. Sci., vol. XLVIII, 1894, pp. 455–472.

seems the most difficult of explanation; but the writer has recently found that the narrows record a second reduction in the amount of fall in the river, before the present descent was established, thus retarding the recession along this section of the gorge, and increasing in part the time compensation for the reduced amount of work performed. However, further discoveries are necessary to fully explain the phenomenon of the narrows. It now seems probable that the error in determining the time required for the recession of the falls through the section of the whirlpool rapids would not affect the computation of the whole age of the river by more than a few per cent.

No less important than the determination of the age of the river was that of the date when the waters of the Algonquin basin (Huron, Michigan and Superior) were first turned into the Niagara drainage, owing to the warping of the land, with the greatest rise occuring along an axis trending N. 28° E.* The date of the diversion of the waters of the upper lakes from the Ottawa to the Niagara valley has been computed by the writer at 7,200 years. This result was obtained from the mean of three distinct methods of computation, varying from 6,500 to 7,800 years.† Mr. F. B. Taylor's more recent estimate gives the range of from 5,000 to 10,000 years.

Niagara as a time piece would be incomplete without indicating the changes in the near future. From the northeastward tilting of the lake region, it was computed that in 5,000 years, not merely Niagara Falls would cease to exist, but also that the drainage of the deepest part of the Niagara river at Buffalo (45 feet) would be reversed and turned into lake Erie, whose outlet would then be through lakes Huron and Michigan into the Mississippi river by

*This direction occurs east of Georgian bay, while at the end of Lake Ontario the direction of rise is N. 25° E. See papers by the writer cited before.

†See Duration of Niagara Falls, cited before.

way of Chicago. This inference was based upon the long delayed discovery of the rate at which the earth's crust has been rising in the lake region, — which was found to be for the Niagara district 1.25 feet per century more than the rate of rise at Chicago.* With this determination it was easy to calculate the rate of terrestrial deformation for other regions, — thus northeast of lake Huron the rise has been found to be two feet per century, and north of the Adirondacks, the warping is progressing at 3.75 feet in a hundred years.

The rate of deformation of 1.25 feet per century, in the Niagara district, was the minimum calculation, with a possible maximum of about 1.5 feet per century. The approximate correctness of the determination has just been confirmed by a paper presented to the American Association, by Prof. G. K. Gilbert, immediately before this communication was read.† He had used the bench-marks at various localities where the fluctuations of the lake levels have been registered the last 20-37 years. While the recorded measurements vary from about one to two and a half inches during the periods of observation, they have been extended over the lake region, with results closely agreeing with the previous determinations of the writer. This will be better understood using Professor Gilbert's application — namely, — that in 500–600 years, the Erie waters would be on a level with those of lake Huron — in 1,000 years they would overflow the natural divide near Chicago — in 2,500 years, the waters would cascade into the Niagara gorge only during high water — and in 3,000 years, the falls would be entirely drained. These changing conditions, based upon the writer's previously discovered rate of terrestrial deformation, would take — 720 years for the Erie and Huron waters to be on the same level; 1,280

* See Duration of Niagara Falls, cited before.

† Modification of the Great Lakes by earth movements. Nat. Geog. Mag., vol. VIII, 1897, pp. 233–247.

years for the overflow into the Mississippi drainage (the artificial canal would reduce this estimate to 720 years); and 2,600 years for the general drainage of the lakes into the Mississippi. In 5,000 years the whole river as far as Buffalo would be drained towards the south.

In spite of taking the minimum rate of recession and the probable errors, the closeness of these results satisfactorily confirms many of the calculations based upon Niagara as a geological chronometer.

This paper, giving the principal results of investigations into the lake history, thus shows the writer to have been greatly affected by the studies of his co-workers. Indeed, all of the researches by the different observers have been very much dove-tailed, so that our present knowledge of the history of the Great Lakes and Niagara Falls is the result of the labors of many individuals. Besides the names of those already mentioned, we should add those of Shaler, Tarr, Wright, Russell, Upham, Kibbe, Lincoln, Brigham and Scovill with the names of Hall and Lyell, too well known to need special mention.

To complete the review, mention should be made of the writings of Mr. F. B. Taylor, in connection with his important survey of the Nipissing outlet of the Algonquin basin, and of the dissected shore lines of the upper lakes; and of the important investigation of Central New York by Professor Fairchild.

APPENDIX.

The recent paper on "Another Episode in the History of Niagara"* by the writer is important in its showing that after the waters of Lake Ontario had reached their lowest state, and the Niagara its highest fall, the waters of the Ontario basin were backed up into the then made gorge, owing to the progressive tilting of the earth's crust at the outlet of the lake, so that the waters rose in the Niagara gorge to a height of 75 feet above their present level, and thus reduced the efficiency of the Falls, while they were receding past the section of the whirlpool rapids; thus this diminished height helps to explain the shallowness of the Niagara river along this section. The waters were again lowered to their present level by the St. Lawrence cutting down its channel more deeply into the rim of the water basin. In this paper there is also a revision of the episode of the Falls, correcting and reducing to greater accuracy the previous investigations.

* Read before the Am. As. Ad. Sc., Boston, Aug , 1898. Published in Am. Jour. Sc., Series IV, Vol. VI, pp. 439-450, 1898; also, Proc. Can. Inst., Vol. I, pp. 101-103, 1898. (This abstract was the first announcement of the collecting of this episode.)